ILLUMINATING ENGINEERING

FEBRUARY 1951

Comfortable Brightness Relationships for Seeing

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Lighting Hazardous Roadway Areas

"X" Factors in Fluorescent Lighting

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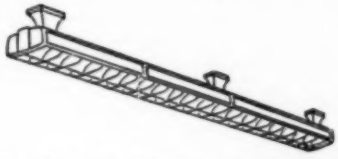

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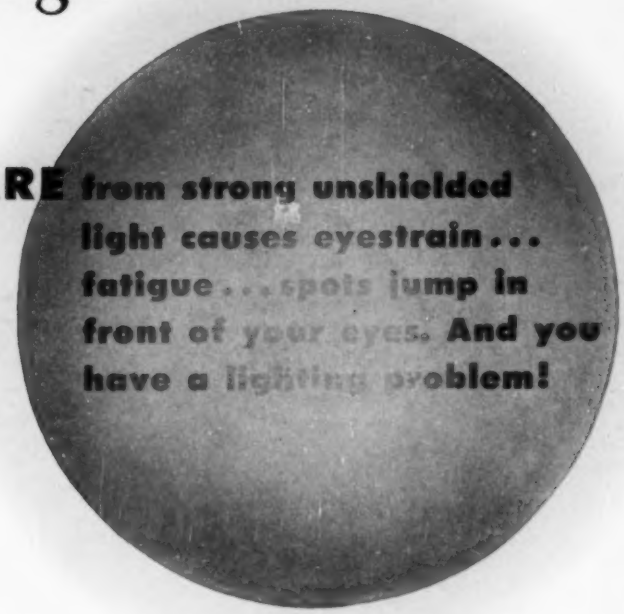
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ILLUMINATING ENGINEERING

THE JOURNAL OF THE ILLUMINATING ENGINEERING SOCIETY

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GENERAL ELECTRIC

The "X" Factors in Fluorescent Lighting

By BENJAMIN SCOTT BENSON, JR.
ERIC H. CHURCH

THE PURPOSE of this paper is to enumerate, discuss and, where possible, to shed some light on several fluorescent lighting perplexities. It was decided to label these perplexities "*X* Factors" since they are most often either unknown or else ignored in lighting calculations. Their neglect does not mean, however, that they are not present and working in their devious ways towards providing the unwary with as fine a set of wrong answers as he could (not) hope to have.

These *X* Factors are oftentimes responsible for the actual illumination results being considerably different from those calculated in the best Handbook tradition. They are generally, but not always, due to the effects of external factors upon the light output of the fluorescent lamps, the combination of lamps with luminaires and, as the end result, the amount of illumination reaching the work plane.

This paper purposely omits what is undoubtedly one of the biggest *X* Factors of all — that of maintenance. Maintenance does not explain the difference so often encountered between initial* calculated illumination and initial* achieved illumination and it is toward the rationalizing of these initial differences that the paper devotes its efforts.

I. Individual Lamps

The variation in the lumen output of the fluorescent lamps themselves might well be considered an *X* Factor. For example, a 40-watt, T-12, 48-inch, white, preheat lamp is usually rated at 2320 lumens at 100 hours of burning. A half-dozen lamps of this type selected at random from a standard package, carefully aged 100 hours and calibrated in a 150-inch integrating sphere (Fig. 1) indicated a range of lumen outputs between 2331 and 2444 — the high delivering approximately 5 per cent more and the average 2½ per cent more than the rating. It is recognized that the sampling was not large nor the difference, of itself, particularly significant. It does indicate, however, the possibility that at least a portion of the difference between calculated and actual illumination could well be due to the chance selection of lamps that were off to one side of the rated output.

II. Individual Ballasts

After consideration of the lamps it is but natural to next consider their control equipment. For any of the more commonly used lamps there are a great many types and makes of ballasts available. A study of the rated electrical characteristics of these ballasts that can be used to operate a given lamp reveal considerable divergence between watts loss, ballast current rating, lamp current, power-factor, etc. Electrical tests of these ballasts show an even wider divergence. The *X* Factor here is the effect that these ballasts have upon the light output when used in combination with the lamps in a luminaire.

To illustrate the possible variation in light outputs under these conditions, ballasts of various types and makes were selected at random and tested in a two-light, closed end, industrial luminaire. As with the lamps, it was not known whether the ballasts selected were low, high or average. They represented ballasts that were pulled off the

Figure 1. The 150-inch integrating sphere.

A paper presented at the National Technical Conference of the Illuminating Engineering Society, Pasadena, California, August 21-24, 1950. Authors: Benjamin Electric Mfg. Co., Des Plaines, Ill.

*at 100 hours of burning.

shelf just as any customer might obtain if he went into a store and purchased them.

With a constant ambient temperature of 80°F and 118 volts supplied to the ballasts the following results were obtained:

Pre-heat, Two-lamp Ballasts — 48-inch, T-12, Bi-pin Lamps

Ballast I (conventional lag-lead) = 100% (assigned) Relative Light Output

Ballast II (conventional lag-lead) = 100.5% Relative Light Output

Instant-Start, Two-lamp Ballasts — 48-inch, T-12, Bi-pin Lamps (I.S.)

Ballast A (series—regulated watts type) = 100.0% (assigned) Relative Light Output

Ballast D (conventional lag-lead) = 103.3% Relative Light Output

Instant-start, Two-lamp Ballasts — 48-inch, T-12, Single-pin Lamps

Ballast A (series—regulated watts type) = 100.0% (assigned) Relative Light Output

Ballast B (series) = 103.4% Relative Light Output

Ballast C (series) = 87.9% Relative Light Output

Ballast D (conventional lag-lead) = 104.4% Relative Light Output

Ballast E (conventional lag-lead) = 110.5% Relative Light Output

The two conventional pre-heat ballasts, while of different makes and ratings were of the same general type and resulted in practically the same results.

The two ballasts used with the instant-start bi-pin lamps were of different make, rating and type.

The five ballasts used with the instant-start single-pin lamps were of different make, rating and/or type and included the two ballasts used with the instant-start bi-pin lamps. The use of Ballast *C*, while of the same general type as Ballast *B*, resulted in only 85 per cent as much light under identical conditions. Similarly, using Ballast *D* resulted in only 94 per cent as much light as Ballast *E*.

III. Individual Luminaires

The range of manufacturing tolerances of the individual luminaires poses another *X* Factor. For a given luminaire design — an industrial type for example — manufacturers are constantly striving to increase the light output efficiency by raising the reflectance of the reflecting surface. Minimum reflectance values are usually set in accordance with accepted standards. Maximum values are limited only by practical considerations such as economics, durability, etc.

A three-light, closed-end industrial luminaire type for 48-inch, T-12 fluorescent lamps usually has a mean light output efficiency set at 72 per cent. Samples of production may run consistently higher than this value by 5 or 6 per cent. When using a coefficient of utilization table based on a light output efficiency of 72 per cent this difference can well show in the result.

IV. Temperature

Fluorescent luminaires are photometered at an ambient temperature of 80°F.[1] The *X* Factor here is what, if anything, happens to the light output at ambient temperatures other than 80°F. Considerable information has been published as to what happens to a bare fluorescent lamp or one enclosed in tubing but little data are available for the more common types of luminaires.

The light output of both the two- and three-lamp closed-end fluorescent industrial type luminaires was investigated under a wide range of ambient temperatures with rated voltage applied to the ballasts which were of the conventional (lag-lead) preheat type. An additional test was made of the three-lamp luminaire with a clear dust-tight cover in order to investigate the effect of completely enclosing the lamps. Ambient temperature was closely controlled by placing the luminaires in a heat-cold chamber (Fig. 2).

The results of the temperature (in still air) tests are shown in Fig. 3. For comparison purposes, one curve is based on information according to Forbes and Diefenthaler[2] for a bare 40-watt, 48-inch, T-12 lamp. As could be expected, the relative light output peaked at a lower temperature for the enclosed three-light luminaire than for the same unit less the cover. Contrary to what one might expect, the

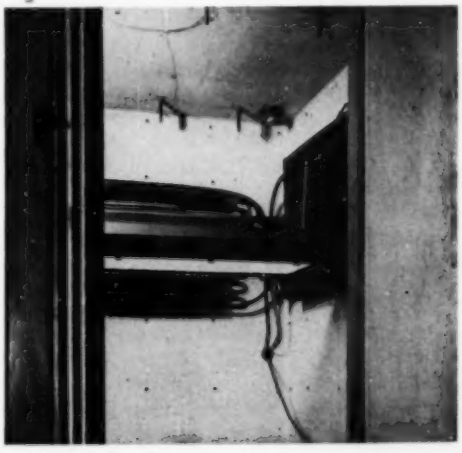

Figure 2. The heat-cold chamber used for temperature tests.

corresponding two- and three-light luminaires tested peaked at approximately the same ambient.

In an industrial plant a temperature at work-level of 72°F does not necessarily mean that the temperature at luminaire level is also 72°F. In some instances temperatures near the ceiling (where the luminaires are oftentimes installed) may be 20 to 30 degrees warmer than at work-level. This means that the lighting equipment may be operating in an ambient temperature roughly 10 to 20 degrees warmer than that at which they were rated. Certainly the drop in the light output indicated for these elevated temperatures is of sufficient value to effect appreciably the resultant illumination.

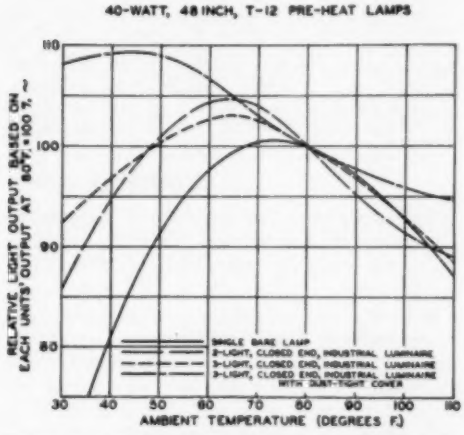
40-WATT, 48 INCH, T-12 PRE-HEAT LAMPS
RELATIVE LIGHT OUTPUT BASED ON EACH UNITS' OUTPUT AT 80°F. = 100 %
110
100
90
80
SINGLE BARE LAMP
2-LIGHT, CLOSED END, INDUSTRIAL LUMINAIRE
3-LIGHT, CLOSED END, INDUSTRIAL LUMINAIRE
3-LIGHT, CLOSED END, INDUSTRIAL LUMINAIRE WITH SLOT-TIGHT COVER
30 40 50 60 70 80 90 100 110
AMBIENT TEMPERATURE (DEGREES F.)

Figure 3. Variation in light output with change in ambient temperature for several fluorescent industrial luminaire types in still air.

V. Drafts

The influence of drafts upon the light output of fluorescent lamps is certainly one of the *X* Factors. Data on draft effects on fluorescent lamps both bare and enclosed in tubing are available.[2, 3] Drafts undoubtedly have some influence on the light output of industrial fluorescent luminaires but the complications involved preclude the inclusion of data which would be indicative. A study of this nature should include the effects not only of air velocity, but direction and humidity as well. The application of such data to an installation would be a major undertaking.

VI. Line Voltage

The *X* Factors should certainly include line voltage. Unless otherwise specified, fluorescent photometric tests are based on a line voltage of 118.[1] Some ballasts indicate this voltage on their cases while others show a range of 110 to 125 volts.

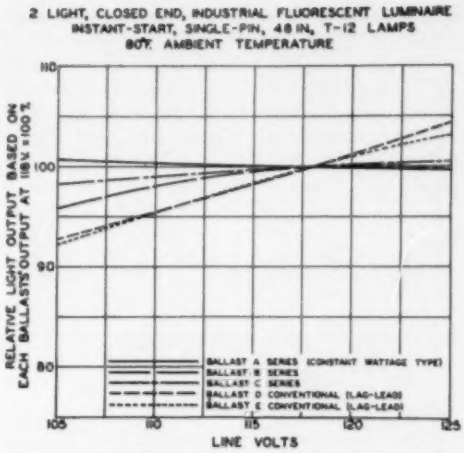
2 LIGHT, CLOSED END, INDUSTRIAL FLUORESCENT LUMINAIRE
INSTANT-START, SINGLE-PIN, 48 IN, T-12 LAMPS
80°F. AMBIENT TEMPERATURE
RELATIVE LIGHT OUTPUT BASED ON EACH BALLAST'S OUTPUT AT 118 V. = 100 %
110
100
90
80
BALLAST A SERIES (CONSTANT WATTAGE TYPE)
BALLAST B SERIES
BALLAST C SERIES
BALLAST D CONVENTIONAL (LAG-LEAD)
BALLAST E CONVENTIONAL (LAG-LEAD)
105 110 115 120 125
LINE VOLTS

Figure 4. Variation in light output with change in line voltage (output with each ballast at 118 v. = 100%).

To investigate this particular Factor a series of tests were run on a two-light, closed-end, industrial fluorescent luminaire with 48-inch, T-12, single-pin lamps and using the five instant-start ballasts previously mentioned in this paper. With the ambient held constant at 80°F the voltage to the ballast was varied from 105 to 125 volts. The results of these tests are shown in Fig. 4 in terms of relative light output for each ballast-lamp combination at 118 volts equal to 100 per cent.

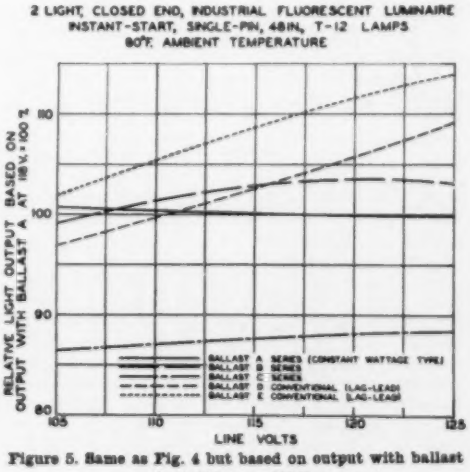
2 LIGHT, CLOSED END, INDUSTRIAL FLUORESCENT LUMINAIRE
INSTANT-START, SINGLE-PIN, 48 IN, T-12 LAMPS
80°F. AMBIENT TEMPERATURE
RELATIVE LIGHT OUTPUT BASED ON OUTPUT WITH BALLAST A AT 118 V. = 100 %
110
100
90
80
BALLAST A SERIES (CONSTANT WATTAGE TYPE)
BALLAST B SERIES
BALLAST C SERIES
BALLAST D CONVENTIONAL (LAG-LEAD)
BALLAST E CONVENTIONAL (LAG-LEAD)
105 110 115 120 125
LINE VOLTS

Figure 5. Same as Fig. 4 but based on output with ballast A at 118 v. = 100%.

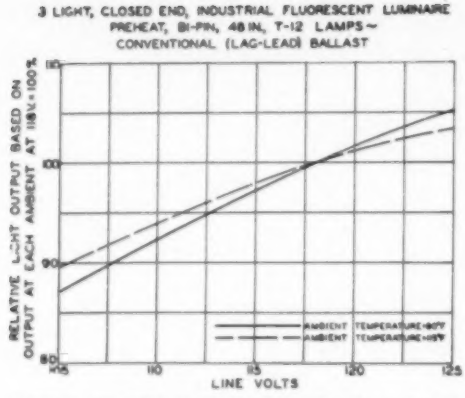

Figure 6. Variation in light output with change in line voltage at different ambient temperatures in still air.

From Fig. 4 it can be seen that all of the series ballasts had less fluctuation in light output than the conventional (lag-lead) ballasts. The curve was plotted in this fashion for the purpose of convenience in studying fluctuations of individual ballasts. For a more realistic comparison of the *actual* light output performance of one to the other Fig. 5 has been included. In this curve the ballasts tested assume their actual relative positions.

In a paper by Gaetjens entitled "Lighting Maintenance in War Industry Plants"[4] it is interesting to note in his summary of maintenance how closely the circuit voltage matched the ballast design voltage. It would appear that the war plants under consideration were blessed with higher line voltages than a great many typical industrial plants. Available voltages between 105 and 110 volts are not uncommon and voltages as low as 90 not unheard of.

Having investigated the separate effects of temperature and voltage on light output the question naturally arises as to their combined effects. Fig. 6 illustrates the relative light output plotted against line volts for a three-light closed-end industrial luminaire at ambient temperatures of both 80 and 115°F. For this particular luminaire, there is less change in light output for a given change in voltage at 115°F than at 80°F. This variation provides another facet to the *X* Factors!

VII. Atmospheric Absorption

The loss of light due to atmospheric absorption in an interior that is clean and well ventilated is, for all practical purposes, nil. In many industrial plants the presence of dust, smoke, steam and fumes may lower the amount of illumination reaching the work plane and presents an additional *X* Factor. The amount by which the resultant illumination will be decreased depends, of course, on a great many variables which well nigh defy cataloguing. For certain industrial areas factors should be "shaded" slightly to provide at least a "degree" of compensation.

VIII. Lighting Calculations

Aside from the actual mechanics of computation *X* Factors may easily and effectively insinuate themselves into the calculation of illumination values.

It is widely recognized that average illumination values based on "point-by-point" calculations will usually be lower than that actually received since the reflections from walls, floor and ceiling are ignored. For this reason the "lumen method" of calculation, which takes reflections into consideration, is ordinarily used.

To illustrate how the unwary may be trapped, examples of seeming capriciousness in the "lumen method" should be considered. The following examples are based on the use of the two-light industrial fluorescent luminaire in rooms having ceiling

MOUNTING HEIGHT ABOVE FLOOR (FEET)

Direct, Semidirect, General Diffuse, Direct-indirect Luminaires		7 to 7½	8 to 8½	9 to 9½	10 to 11½	12 to 13½	14 to 16½	17 to 20	21 to 24	25 to 30	31 to 36	37 to 50
ROOM WIDTH* (Feet)	ROOM LENGTH* (Feet)	ROOM INDEX										
24 (22–26)	22–30	D	E	E	F	G	H	I	J	J		
	30–42	C	D	E	F	G	G	I	J	J		
	42–60	C	D	D	E	F	G	H	I	J	J	
	60–90	C	D	D	E	F	F	H	I	J	J	J
	90–140	C	C	D	E	E	F	G	H	I	J	J
	140–up	C	C	D	E	E	F	G	H	I	I	J
30 (27–33)	27–42	C	D	D	E	F	G	H	I	J	J	
	42–60	C	C	D	D	F	F	H	H	I	J	
	60–90	B	C	C	D	E	F	G	H	I	J	
	90–140	B	C	C	D	E	E	F	G	H	I	J
	140–180	B	C	C	D	E	E	F	G	H	I	J
	180–up	B	C	C	D	E	E	F	G	H	I	J

Figure 7. Reproduction of a portion of Table 8-3, I.E.S. Handbook—Room Index Table.

reflectances of 50 per cent and walls 30 per cent. Room index values have been taken from the partial table show in in Fig. 7.

Example I:

	Room A	Room B	Room C	Room D
Room dimensions	22'x30'6"	26'x41'6"	27'x42'6"	33'x59'6"
Mounting height from floor	16'6"	12'	11'6"	9'
Room Index (from Fig. 7)	G	G	D	D
Coefficient of Utilization	.51	.51	.64	.64

According to Example I, generous increases in room dimensions and substantial reductions in mounting heights when comparing Room *A* to Room *B*, or Room *C* to Room *D* make no difference in the coefficient of utilization. However, there is a narrow zone (between Room *B* and Room *C*) where increasing the room dimensions but 12 inches each way and lowering the mounting height only 6 inches increases the coefficient of utilization by over 25 per cent.

Example II:

	Room W	Room X	Room Y	Room Z
Room dimensions	30'x50'	30'x50'	30'x50'	30'x50'
Mounting height from floor	16'6"	12'	11'6"	9'
Room Index (from Fig. 7)	F	F	D	D
Coefficient of Utilization	.53	.53	.64	.64

According to Example II a change in mounting height of 30 inches or more makes no difference in the coefficient of utilization when comparing Room *W* to Room *X*, or Room *Y* to Room *Z*. However, the decrease of only 6 inches in mounting height for Room *Y* compared to Room *X* increases the coefficient of utilization by almost 21 per cent!

"Borderline" rooms such as *B* and *C* and *X* and *Y* can introduce errors of considerable magnitude into lighting calculations if the Room Index tables are religiously followed without interpolation. At the present time the Illuminating Engineering Society is working on new tables of Room Index values which will aid materially in relieving the present ambiguities of the system. Until such data are available in the field this particular *X* Factor may cause trouble.

Conclusions

There are other *X* Factors which could be mentioned if space permitted. It is believed, however, that the ones discussed are quite representative of the variables present in fluorescent lighting applications. Some of the Factors are large — some are small — some are benign — some are malign. It is quite within the realm of possibility that under certain happy combinations of Factors the debit and credit side of the "lighting ledger" would balance out and the results obtained equal those calculated. This would no doubt be the exception rather than the rule.

While this paper reports the results of samplings which may be inconclusive, it does point out the following needs:

1. A standardization of performance (consistent with quality) of ballast equipment.
2. Photometric tests of luminaires based on the light output of the lamp-ballast-luminaire combination rather than on the assumption that the lamp-ballast combination is delivering rated lumens.
3. The development, when possible, of fluorescent lamps that will deliver peak light output higher on the temperature scale.
4. Further study of the combined effects of temperature and line voltage on the light output of the actual lamp-ballast-luminaire combinations so that correcting factors can be applied where required in lighting calculations.
5. Greater refinements in the "lumen method" of calculations — particularly in the room-index tables.

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DISCUSSION

ROY A. PALMER*: We have often found considerable discrepancies between our calculated illuminations and that actually achieved after the job is installed. We attributed these differences to the possible variation in lamps and to inaccurate lumen output figures published by lamp manufacturers.

According to the authors of this paper, our assumptions were perhaps correct regarding differences individual lamps. Even though the measurements of only half dozen lamps reported in this paper are not comprehensive enough to be acceptable as a significant contribution to explain discrepancies, it nevertheless indicates the need for narrower manufacturing tolerances and the publishing of lumen output figures as accurately as possible by manufacturers. The authors are too mild in their statement that individual lamp outputs present "the possibility that at least a portion of the differences between calculated and actual illumination could well be due to the chance selection of lamps—." Further study no doubt would very considerably amplify and make more emphatic that statement.

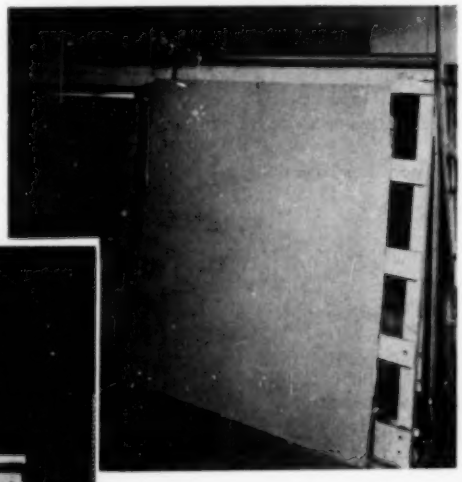
*Duke Power Co., Charlotte, N. C.

It has always been my impression that ballasts have been more responsible for illumination variations than any other factor. This paper substantiates this belief. While a great deal of work has been done on ballast design and construction, we can clearly see the need for much more study and attention to this important part of the lighting system.

Where one considers the many "X Factors" which can be present to render illumination calculations inaccurate, it may have the effect of weakening the confidence in present design methods. This may be true among some young engineers and especially among salesmen of lighting equipment who may feel that calculations might show up their equipment in an unfavorable manner or since it isn't dependable, why take the time and effort to bother with calculations at all.

One of the values of this paper is the enumeration of the many fallacies which may occur in illumination calculation due to the fixture design. It shows very clearly that lighting equipment manufacturers need highly trained illuminating engineers to contribute their knowledge toward the ultimate design of a fixture. Artists who know only how to create an attractive looking fixture are not enough. Engineering features such as electrical circuits, control of light, factors involving heat and ventilation, coefficients of utilization and similar items are a definite requirement. Yet to examine many fixtures on the market today — even those by good, reputable manufacturers, reveals a deplorable lack of incorporation of engineering knowledge to create a creditable, high type fixture.

Lighting for Industrial Inspection



Defects, such as dents, in this etched zinc plates are shown up when it is inspected under light at a grazing angle from eight R-40 lamps (left). When the plate is illuminated only by general room lighting (above) the defects are not easily detected. Installation at Copifyer Lithograph Corporation, Cleveland, Ohio. Photo courtesy of General Electric, Nela Park, Cleveland, Ohio.

A Recording Daylight Illuminometer

By NORMAN B. FOSTER

A recently-developed photoelectric illuminometer for recording daylight illumination is herein described. Horizontal exposure is achieved by means of an opal glass collecting disk. The sensing element consists of an improved type barrier layer cell and the record is obtained on a self-balancing potentiometer recorder. Laboratory data are presented here to show that the illuminometer has a straight-line response to light, that it is relatively insensitive to ambient temperature, that its collector closely follows Lambert's Cosine Law and that its spectral response is quite similar to that of the human eye. Uses and method of calibration of the illuminometer are discussed.

THE WEATHER BUREAU has for many years been measuring the intensity of solar radiation on the earth's surface at various locations throughout the United States. The pyrheliometer used for these measurements is a radiation thermopile and is usually exposed horizontally. Energy is measured in gram calories per square centimeter per minute.

During the past several years there has been an increasing interest in the measurement of daylight illumination — that part of solar radiation visible to the human eye. The electric light and power industry is interested in this measurement because of the correlation between daylight illumination intensity and power load associated with electric lighting. Agricultural researchers and foresters are becoming more and more interested in studying the correlation between daylight intensity and plant growth. Other interested parties are illuminating engineers, architects, test engineers, biological researchers.

The Weather Bureau, having been repeatedly consulted regarding practical field equipment for measuring and recording daylight illumination intensity, has developed recording daylight illuminometer equipment which, it is expected, will become more or less standard for this measurement.

Manner of Exposure

An illuminometer may be exposed spherically, hemispherically, normal to the sun, or on a horizontal plane. The horizontal exposure was chosen because (1) it gives an integrated value of all the light striking the surface from all parts of the sky. The light incident on a horizontal surface, such as a work table, is usually that in which we are most interested. (2) The horizontal surface collector is simple to construct and easy to calibrate. (3) Inasmuch as the Weather Bureau has been exposing the pyrheliometer in this manner for the past thirty-five years, correlation between illuminometer and pyrheliometer data will be greatly facilitated.

The principal factors to be considered in the design of an illuminometer are (1) choice of a light sensitive element, (2) linearity of the cell response, (3) conformity of the light collector plate to Lambert's Cosine Law, (4) effect of ambient temperature on the cell response, (5) agreement of the spectral response of the illuminometer to that of the human eye, (6) manner of housing the various components, (7) photometric units of measurement, and (8) characteristics of the recorder.

Author: United States Weather Bureau, Washington, D. C.

The Sensing Element

In a light sensitive element the first important requirement is that of stability. To be satisfactory, it should hold its calibration for months or even years, if possible. Second, response should be directly proportional to light intensity. And third, the response should be great enough to be made to operate a recorder. In general, black body receivers such as radiation thermocouples have these characteristics, but they also have other characteristics which make them undesirable for the purpose of measuring daylight. One of their chief drawbacks is that when the luminosity filter is used to exclude all radiation except that visible to the eye, the filter, because it absorbs energy, is heated. It then becomes a source of radiant heat which tends to change the temperature of the receiver. This in turn causes a drift in its zero or the dark current response. There are ways of correcting for this heat response but in so doing the equipment may become unduly complicated.

The selenium barrier layer type photocell was next tried. This type has many characteristics which naturally fit it for the purpose of measuring daylight. First, it has very little response out in

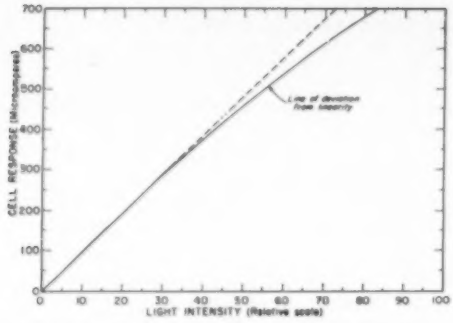


Figure 1. Deviation from linearity, Weston Photronic cell Type 856RR, across 200 ohms. (Composite data from 10 cells.)

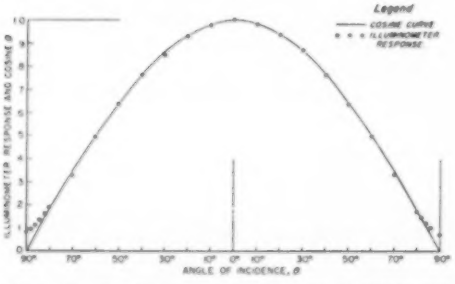


Figure 2. Angular response of typical illuminometer. (Surface of opal glass receiver set ⅛" above housing.)

the infrared end of the spectrum; thus when a luminosity filter is placed over it, the radiation due to the heating of the filter does not appreciably affect the cell's response. Second, it has a spectral response somewhat similar to that of the human eye. Finally, it is a self-generating type cell with a sensitivity to light so great that its current output under daylight is large enough to operate a meter or recorder without resort to electronic or other types of amplifying equipment.

Preliminary tests disclosed that it also had the undesirable characteristic of occasionally changing its sensitivity, sometimes radically. It was noted that a change in sensitivity often occurred after moisture had worked into the cell due to heating and cooling in outdoor exposures. Tests were made to improve the performance by hermetically sealing the illuminometer. This was accomplished, but with difficulty.

A more satisfactory solution, however, was hermetically sealed barrier layer cells. The cells were sealed by soldering the cover glass to a metal capsule surrounding the unit. The soldering to the glass was accomplished by first evaporating metal to its edge. To insure the elimination of all moisture from the cell surface, the capsule was first evacuated and then filled with a dry inert gas. Cells sealed in this manner showed no appreciable shift in sensitivity when exposed. Some of them have been checked periodically for the past two years and found to be quite stable. Various manufacturers now offer hermetically sealed barrier layer cells commercially.

Linearity of Response of the Barrier Layer Photocell

Linearity of the cell's response to light was found to be excellent throughout the range needed for recording daylight. The barrier layer photocell is generally used as a current generator and, within limits, may be considered a constant current generator. However, as the external resistance increases for a given amount of light or as the light increases for a given external resistance a point is reached where the cell begins to deviate from linearity, due to the development of a back emf. It is necessary, therefore, to keep the external resistance low. However, enough resistance must be used so that the IR drop across the external resistance will operate the indicator or recorder. It was found that with 200 ohms in the external recuit most cells will develop at least 200 microamperes before departing appreciably from linearity of response (see Fig. 1). Since 200 microamperes across 200 ohms is more than enough to operate many commercial potentiometer recorders this value is considered satisfactory. All data given in this paper were taken with the cell operating across 200 ohms, with the exception of the data for the spectral response curve, Fig. 5, made at the National Bureau of Standards. Here a higher value was chosen because of the low light intensity emerging from the spectrometer. The current, however, was sufficiently low that linearity was strictly maintained.

Agreement with Lambert's Cosine Law

It has been pointed out that if the illuminometer is to measure accurately the vertical light coming from all parts of the sky it must respond as a cosine receiver. That is, the surface should be so irregular that it will diffuse the light equally in all directions rather than reflect it in a single direction for a given angle of incidence as does a mirror. Accordingly, the collecting surface first tried was a good grade of pot opal glass etched or roughened

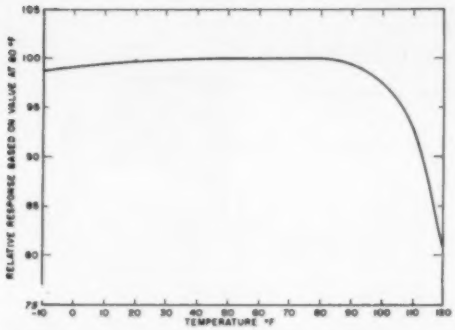


Figure 3. Response vs. Temperature, Weston Type 856RR, early sample of hermetically sealed cell.

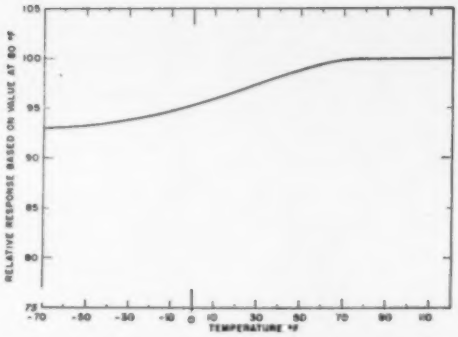


Figure 4. Response vs. Temperature, Weston Type 856RR improved hermetically sealed cell (composite data from six cells).

to a mat finish. The etched surface, however, was very difficult to keep clean. In fact, when exposed to city smoke and dust it often became permanently discolored. A smooth-surfaced opal glass disk was then tried and proved to be a very good cosine receiver at small angles of incidence but performed more and more like a speculum as grazing incidence was approached. This difficulty was overcome by raising the edge of the glass disk about one- eighth inch above the surface of the cell housing. The light passing through the edge of the disk then just about compensates for the light lost by specular reflection from its surface. A typical cosine-response curve of the illuminometer is shown in Fig. 2.

Temperature Effects

Preliminary work by this laboratory on the barrier layer cell indicated that its response for a given light intensity was dependent to some extent on the ambient temperature. The first hermetically sealed cells tried were affected very little by temperatures below 85 or 90F. At temperatures higher than this the response dropped off increasingly rapidly until at 120F it was about 20 per cent low (see Fig. 3). Many of the cells checked subsequently did not do even this well. However, an improved type of cell became available during the past year which laboratory tests indicate as having only a few per cent spread in response from —70F to 120F (see Fig. 4). By calibrating the cells at an intermediate temperature, it is possible to obtain a calibration accurate to within two or three per cent, regardless of the extremes of temperature to which the cell may be exposed. This is considered sufficiently accurate for daylight illumination measurements.

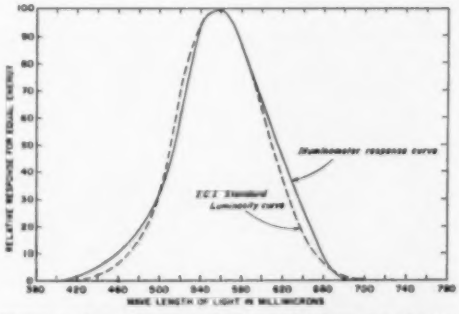

RELATIVE RESPONSE FOR EQUAL ENERGY
Illuminometer response curve
I.C.I. Standard Luminosity curve
WAVE LENGTH OF LIGHT IN MILLIMICRONS

Figure 5. Spectral response of the illuminometer at normal incidence compared to the I.C.I. Standard Luminosity Curve, made at National Bureau of Standards, Radiometry Section, July 1950.

Spectral Response

The barrier layer cell responds to some extent beyond both ends of the visible spectrum; its cutoff on the lower wavelength side is about 300 millimicrons while on the long wavelength side it responds to a little more than 760 millimicrons. Fortunately, glass filters have been devised which, when placed over the cell, absorb the extra wavelengths at both ends so that it has a spectral range which approximates that of the human eye. Fig. 5 shows the response curve of the illuminometer as compared with the theoretical response curve of the human eye. This curve was made at the National Bureau of Standards in July 1950. It represents the response of the barrier layer cell operating through the filter used to correct for luminosity and the pot opal collecting disk. It will be noted from the curve that the point of the maximum sensitivity of the eye and the illuminometer are nearly identical.

Figure 6. Weather Bureau illuminometer.

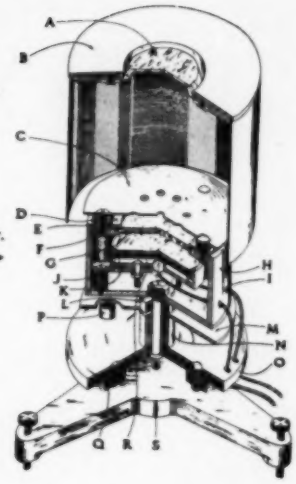


Figure 7. Housing details of illuminometer.

Illuminometer Components

Relationship of the component parts and the manner in which they are housed are shown in Figs. 6 and 7. All parts are made from non-corrosive materials. The outer surface of the case is either chromium plated or covered with a good grade of baked-on enamel. Referring to the letters in Fig. 7: The smooth opal glass collecting plate (A) is held in place by fiber ring (E). The top of the housing (B) is beveled to prevent grazing reflections from the housing to the raised disk and also to keep water from collecting about the disk. The perforated disk (C) serves as a diaphragm to limit the cell response to suit the recorder. Letters (G) and (R) refer to the luminosity filter and barrier layer cell respectively. Plate (M) is a baffle to prevent any stray light from reaching the cell from below. The ventilating ducts (P) are filled with glass wool to prevent dust from filtering in and settling on the optical components. The illuminometer is supported on a tripod base with leveling screws.

The Recorder

Before a complete specification for the recorder could be written it was necessary to specify the units in which the measurements were to be made. Of the many different units that can be used, the footcandle was chosen as the unit generally preferred by illuminating engineers in the United States. Measured on this scale, daylight illumination varies from about one at sundown on a dark cloudy day to about 10,000 on a clear day when the sun is high.

The salient recorder characteristics specified are:

(1) Type: Self-balancing potentiometer,
(2) Scale: 100 divisions, each division representing 100 footcandles,
(3) Chart speed: 2 inches per hour,
(4) Chart: Strip, each longitudinal line representing 10 minutes of time,
(5) Range: Adjustable, 3 to 6 millivolts full scale. Applied potential obtained by means of illuminometer connected across 200 ohms,
(6) Accuracy: ±.020 millivolts full scale,
(7) Sensitivity: Not less than .03 millivolts,
(8) Speed of Response: 15 seconds or less full scale,
(9) Record: Trace by fountain pen,
(10) Standardizing Circuit: Automatic at regular intervals and manually when desired,
(11) Power Supply: 110-volt, 60 cycle single phase.

Calibration and Application

Before being placed in operation the Weather Bureau illuminometers are carefully calibrated against a standard lamp in the laboratory. To check calibration after installation a portable standard instrument has been devised which can be set up beside the station instrument. The portable standard, a slightly modified station instrument connected to a microammeter, is calibrated in the laboratory before and after being sent out.

The Weather Bureau has five pilot installations of this equipment located in various Eastern cities, made primarily for correlation between daylight intensity and the power load associated with electric lighting. Since the power companies are more interested in values of low illumination, 2000 footcandles and under, nonlinear-scale recorders are specified. The scale is greatly expanded on the lower end and compressed on the higher end. However, where there is equal interest in both high and low levels of light intensity, as in the case of experimental work involved with the growth of plants, a conventional straight-line response recorder should be used. The Weather Bureau has one of these in operation in Washington.

Lighting a Classroom

LIGHTING OBJECTIVE: To illuminate a classroom using a luminous ceiling.

Installation at Hyde School, Newton, Massachusetts.

General Information: Surface characteristics of this 33 by 24½ foot elementary school classroom are as follows:

Side walls	cream	76% RF
End walls	green	63% RF
Floor	natural wood	50% RF
Desk tops	natural wood	50% RF
Ceiling		
Plaster	white	80% RF
Equivalent reflectance of luminous ceiling		70% RF
Chalkboard	green	25% RF

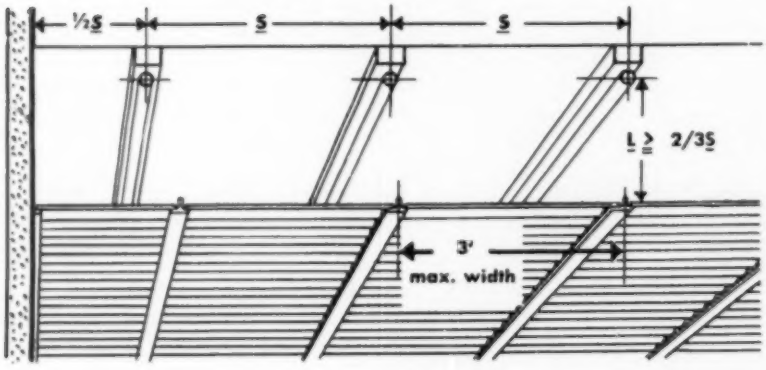
The plaster ceiling is 12½ feet high.

(over)

A.I.A. File No. 31/14

Installation: Twenty-eight 4500K 96-inch T12 fluorescent lamps are mounted in continuous rows above a ceiling of .007 inch thick Marlux corrugated plastic sheeting (manufactured by Martin Electric Products, Inc.). The plastic is mounted 10½ feet above the floor. After 500 hours operation average illumination on a plane 30 inches above the floor measured 65 footcandles. Brightnesses were as follows:

Ceiling	87 ft-L
Walls	
Front	27 ft-L
Side	39 ft-L
Chalkboard	9 ft-L
Floor	17 ft-L
Desk tops	30 ft-L
White paper (80% RF) on desk	54 ft-L



Typical Mounting

The plastic material can be rolled back to relamp the ceiling and is removable for washing.

Lighting data submitted by Domina Eberle Spencer, The University of Connecticut, Storrs, Connecticut, as an illustration of good lighting practice and to aid in the design of similar installations.

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Comfortable Brightness Relationships for Critical and Casual Seeing

By SYLVESTER K. GUTH

This paper presents additional basic and practicalizing data which substantiate the relationships established in the fundamental phases of this extensive series of researches. The relationship between the brightness of a source which produces a sensation of distraction and its position in the visual field has been determined. The results of the series of investigations in a simulated visual environment illustrate how the factors of size, brightness, position and number of sources, and the adaptation brightness may be combined to determine whether a lighting installation can be expected to be comfortable or uncomfortable for most of those who may occupy the area.

THE GOAL of the art and science of illuminating engineering is to provide in visual environments a proper balance of certain controllable factors which influence human performance and comfort. In general, these factors may be combined into the single element of brightness. That is, the brightnesses of various areas are dependent upon the characteristics and positioning of luminaires and lamps and upon the reflectances of the areas. In other words, the goal is to provide brightness relationships (or quality of lighting) which produce the most satisfactory seeing conditions. Thus brightness engineering has become an overwhelmingly important aspect of the more inclusive field of illuminating engineering.

In a previous paper,[1] there were presented the results of an extensive series of investigations of the effects of sources of brightness in the visual field upon comfort and discomfort. This paper was confined chiefly to the basic relationships among

1. The brightness of a source or luminous area,
2. The visual size of the source,
3. The position of the source in the visual field, and
4. The brightness-level to which the eyes are adapted.

These relationships were established for an average observer and are useful for determining the relative influence of each of these factors. Data for various combinations of multiple sources and for a linear source made possible a limited rationalization with lighting practice. Glimpses were given of the manner by which these basic data could be practicalized and used for evaluating the visual comfort or discomfort of a lighting installation. However, certain aspects required further substantiation to insure that the tentative conclusions were based upon sound premises and could be used for evaluating lighting systems. Furthermore, it was believed desirable to introduce a sensation level other than that which was the borderline between comfort and discomfort (BCD).

The present paper presents the results of an additional series of investigations involving the evaluation of sources of brightness by a representative group of observers while performing critical seeing, the extension of the concept to a lower sensation level corresponding to distraction, and a simulated visual environment. The observers used in these investigations were the same group of ten representative observers used in the original series of investigations.[1] That is, they were so selected as to be representative of the 50 subjects used for the determination of the standard average BCD brightness. These new results and analyses make possible a simple and logical method of calculation to determine the permissible brightnesses of sources in a visual environment or the expected degree of sensation which might be induced by proposed or existing lighting equipment.

A paper presented at the National Technical Conference of the Illuminating Engineering Society, Pasadena, California, August 21-24, 1950. Author: Engineering Division, General Electric Company, Nela Park, Cleveland, Ohio.

Critical Seeing

Since seeing is a dynamic activity of human beings, any concept of the evaluation of brightnesses in the visual field should take cognizance of a variable line of visual fixation and of the work-world demands of a critical visual task. The former has been considered in the evaluation of the basic factors which included the direct and indirect viewing of sources of brightness. It was pointed out that sources displaced from the normal line of vision while a worker is performing a visual task may be fixated directly, or nearly directly, when he raises his eyes for relaxation or to view another task-area. However, often the sources are

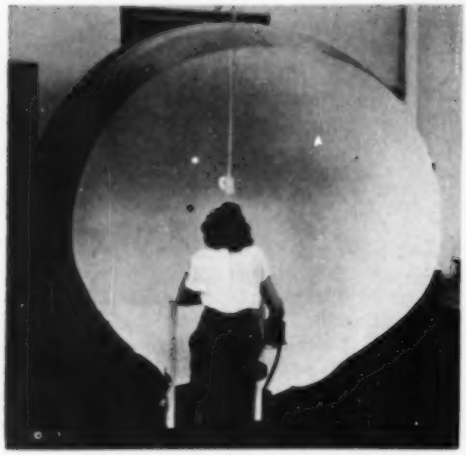

Figure 1. The experimental environment used for determining the relationships between the brightness *B* of a source and its angular distance ϕ above the line of vision for the BCD and distraction sensations while the observers were performing a task of critical seeing. The visual acuity test object was located at the point *X*.

located so as to be annoying and distracting rather than uncomfortable even when the line of vision is below the horizontal. That is, the sensation of brightness is induced while workers are performing tasks which require various degrees of critical seeing. The basic BCD relationships were obtained for conditions which excluded the factor of critical seeing. In other words, the entire attention of the observers was devoted to the evaluation of the sensation produced by a source of brightness. Therefore, a critical visual task was included in the present experimental technique. Thus, the observers were required to evaluate the sensation induced by a source of brightness while they were performing a critical task.

The experimental situation used in this series of investigations was the same as that used in the basic phases previously reported[1] and consisted of a portion of an 80-inch photometric sphere in which the observer's head was positioned so as to locate his eyes at the center. The arrangement is illustrated in Fig. 1. The eyes were at a distance of 40 inches from the inner surface of the sphere which occupied the entire unrestricted visual field. The brightness of this inner surface was maintained at a constant level of 10 footlamberts. Light sources mounted behind 1.48-inch diameter circular openings in the surface of the sphere provided the sources of brightness which the subjects were required to evaluate. At the viewing distance of 40 inches, each source subtended a solid angle of 0.0011 steradian. The sources were located at angles of 10, 20, 30 and 40 degrees, respectively, above the horizontal line of vision.

The critical task which the observers were required to perform while evaluating the sources brightness involved the determination of visual acuity. The apparatus consisted of the Ives-Cobb crossed-grating test object[2] in which the observers were required to resolve a series of horizontal parallel lines. It was located on the line of vision immediately behind a circular opening in the surface of the sphere. The brightness of the visual acuity apparatus was the same as the surrounding field brightness. The observers made continual settings of threshold discrimination of the horizontal lines while they simultaneously adjusted the brightness of the source until the latter produced the required sensation. Since the brightnesses were adjusted to be either at the borderline between comfort and discomfort (BCD) or just barely distracting rather than causing a reduction in ability to see, the observations of visual acuity were essentially constant throughout the entire series of investigations. This provided a good check to determine whether the observers were employing the desired criterion.

BCD sensation. — In this part of the investigation the observers were required to adjust the brightness of the test-source until the sensation produced by it was at the borderline between comfort and discomfort or the BCD sensation. At all times the observers viewed the visual acuity test object directly and were required to evaluate the brightness of one of the four test-sources which was "seen" by averted vision. In other words, their visual attention was concentrated upon the visual task and their mental attention was divided between the task and the source of brightness.

Two methods were used for presenting the source for evaluation. The first method was identical to that used for the determination of the basic relationships in which the test-source was exposed for three one-second "on" periods separated by one-second "off" periods and followed by a five-second "off" period. The five-second period was provided so that the observers could resolve the sensations received during the "on" periods and alter the brightness of the source for the next appraisal if they wished. They were permitted as many 10-second cycles as they deemed necessary to make a complete appraisal for each position of the source.

The second method of presenting the source of brightness involved continuous exposure. That is, the test-source was "on" during the entire test-period and the observers could adjust its brightness at will. Each observer was permitted as long a

TABLE I.

Brightnesses at the borderline between comfort and discomfort (BCD) and at the borderline of distraction of circular sources (subtending 0.0011 steradian) located at various angles (θ) above the horizontal line of vision. The evaluations of brightness were made while the observers were performing a task of critical seeing with task and field brightnesses of 10 footlamberts. The sources were exposed to view momentarily and continuously.

	Brightnesses in Footlamberts			
	Angle θ above line of vision in degrees			
	10	20	30	40
A. BCD, continuous exposure of sources	643	2085	4195	8784
B. BCD, momentary exposure of sources	846	1935	3811	8829
Average (A-B)	745	2010	4003	8806
C. Distraction, continuous exposure of sources	454	988	2458	6200
D. Distraction, momentary exposure of sources	45	135	347	944
E. BCD sensation, momentary exposure, not performing task of critical seeing (Obtained from basic relationships)	1344	1764	2764	4452

period as he deemed necessary to make an adequate appraisal for each position of the source.

The average BCD brightnesses as determined by the representative group of observers for continuous and momentary exposure of sources at various angles above the horizontal line of vision are presented at *A* and *B*, respectively, of Table I. An analysis of the individual observations made by the observers indicates no significant difference between the observed BCD brightnesses determined with the two methods of exposing the sources. Therefore, the data have been averaged and are represented by the line *A-B* in Fig. 2. It is seen that the brightness of the source for the average BCD sensation increases geometrically for equal linear displacement from the line of vision. For example, increasing the angular distance between a source and the line of vision by five degrees would permit about a 50 per cent increase in brightness in order to maintain the sensation at BCD. Similarly, a 10-degree greater displacement permits the doubling of the brightness of the source.

It is of interest to compare the average data (*A-B*) for critical seeing with the results obtained in the original investigation of the effects of various angular displacements of a source above the line of vision. In the latter case, the results are for momentary exposure of sources when the observers were *not* required to perform a task of critical seeing while they were evaluating the brightnesses of sources. These data are included on the last line of Table I and are represented by the dotted line *E* of Fig. 2. Equal linear displacements of the source above the line of vision permit geometrical increases in the brightness for the same sensation, being approximately a 50 per cent increase in brightness for a 10-degree greater dis-

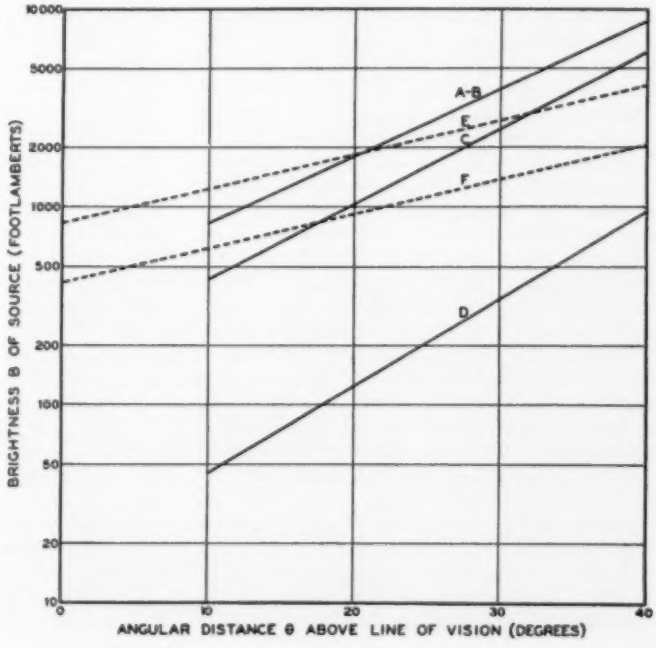

Figure 2. The relationships between brightnesses *B* and the angular displacement θ of sources above the line of vision for BCD and barely distracting sensations when the observers were performing a task of critical seeing. The solid lines represent the observed data for the average BCD sensation for both continuous and momentary exposure of sources, *A-B*, and the distraction sensation for continuous, *C*, and momentary, *D*, exposure of sources. The broken lines *E* and *F* represent the average and lower limits of BCD brightness, respectively, for casual seeing.

placement of the source. This is approximately one-half of the permissible increase in brightness for an equal additional displacement of the source for the condition when the observers are performing a task of critical seeing. Since the same observers were used in both investigations, the results representing casual or non-critical seeing, *E*, and critical seeing, *A-B*, are directly comparable. The relative brightness may be increased more per unit angular displacement of a source for critical seeing than for casual seeing. However, when sources are located close to the line of vision, at angles less than 20 degrees, the permissible BCD brightness is less when critical seeing is involved. For greater angular displacements, the permissible BCD brightness is greater while performing critical seeing. In other words, for a source of a specific brightness which is located within a 20-degree zone from the line of vision, the sensation will be less comfortable for critical seeing than for casual seeing. Similarly, the sensation induced by a specific source located outside of the 20-degree zone will be less comfortable for casual seeing.

These results are logical and are to be expected. Obviously, the judgment of the sensation received from a specific source of brightness is governed by the various demands made of an observer. If the attention of a worker is concentrated upon a difficult visual task, his evaluation of comfort or discomfort can be expected to be influenced by the proximity to the task of a source of brightness. Furthermore, his awareness of the source will be an inverse function of his concentration upon the task. The greater the angular separation between the source and the task, the less will be his awareness of the source and the greater the permissible BCD brightness. As the angular separation is decreased, the source will interfere more and more with the performance of the task and hence a lower brightness will be selected for the BCD sensation. Thus the actual brightnesses for the BCD sensation are dependent not only upon the position of a source in the visual field but also upon the occupational demands made of the worker. Nevertheless, it is possible that a source may be viewed directly or nearly directly, especially when a worker raises his eyes from a task. Therefore, it is important to reduce the brightnesses of sources so that they will be at BCD or less for any activity that may be carried on in the particular visual environment.

Distraction. — A sensation at the borderline between comfort and discomfort is a valid one when non-critical or casual seeing is involved. However, when a worker is concentrating upon a visual task, brightnesses that otherwise are considered to be comfortable may provide a disturbing influence and be distracting. In other words, the peripheral visibility of the source of brightness may be of such magnitude that it competes with the visibility of the task. Therefore, the experiment was repeated with identical conditions except that the observers were required to adjust the brightness of the source so that it was just barely distracting. Measurements of visual acuity and evaluations of brightness were made simultaneously as previously described. Momentary and prolonged exposures of the sources were included in the evaluations of brightness.

The average brightnesses which proved to be just barely distracting are presented at *C* and *D* in Table I for prolonged continuous and for momentary exposures, respectively. The data are represented by lines *C* and *D*, respectively, of Fig. 2. The differences between the brightnesses that are just barely distracting for momentary and prolonged exposure are to be expected. A momentary or flashing source displaced from the line of vision corresponds to movement in the peripheral field. Since a source of brightness possesses a relatively high visibility even when seen by averted vision, it can become annoying and distracting. That is, the source introduces a conflict between two objects, one of which is required to be seen and the other is not desired to be seen but cannot be avoided.

The graphical representations for critical seeing, as illustrated by the solid lines of Fig. 2, are essentially parallel. Thus, on the average, when critical seeing is involved, and the sources are exposed to view continuously, the brightness which produces a sensation of distraction is about 60 per cent of the BCD brightness. However, when the sources are exposed momentarily, the distraction brightness must be reduced to approximately eight per cent of the BCD brightness. In terms of distraction, momentary exposure of sources requires that the brightness be about 13 per cent, on the average, of the permissible brightness for prolonged exposure.

The broken line *E* of Fig. 2 represents the permissible increase in source brightness as the source is displaced at various angles above the line of vision. This relationship is for non-critical or casual seeing and is in terms of the average brightness which produces a sensation at the borderline between comfort and discomfort or average BCD. As was emphasized in the previous paper,[1] the average BCD value merely means that *half* of any given group can be expected to find the sensation to be at, or more comfortable than, the borderline between comfort and discomfort. Similarly, the average value which produces a sensation of distraction can be expected to satisfy only 50 per cent

of a given group. Usually it is desirable to provide a visual environment which will be satisfactory for most of those who will be required to work in that area. Therefore, lower brightnesses are indicated. If, for example, the brightnesses represented by the broken line *E* are reduced to 50 per cent of their values to those indicated by the lower broken line *F*, the resultant sensation would be expected to be less than BCD for most of the group. This certainly would be the brightness relationship which approaches the ideal condition. Thus the range of brightnesses included between the two broken lines *E* and *F* is that which would be expected to provide relatively comfortable brightness conditions.

Since the line of vision usually is directed appreciably below the horizontal while a worker is performing a task, sources of brightness which might be uncomfortable or distracting usually will be displaced 30 degrees or more from the line of vision. They will be near the line of vision only when the worker is not performing the task. In the former case, the lower BCD brightness indicated by *F* will be expected to be comfortable and not distracting. If there is a possibility that the sources may be viewed nearly directly when a worker raises his line of vision, then the permissible brightness must be determined for a smaller angular displacement. For example, if a source of the size used in these investigations (1.48 inches in diameter viewed at a distance of 40 inches) were adjusted to a brightness of about 400 footlamberts, it would be expected to be comfortable for most of those who may view it directly and when not performing critical seeing. If, when critical seeing is involved, this same source were located at an angle of about 10 degrees above the line of vision, it would be expected to be just barely distracting to the average observer. When located at angles greater than about 20 degrees, the source would not be expected to be distracting to even the more sensitive observers. The latter angular distance is considered to be representative of the usual lighting situation.

A Simulated Visual Environment

Any basic investigation of the various individual factors which combine to provide comfortable or uncomfortable, pleasant or distracting, visual conditions must be extended by relating their empirical characteristics and relationships to actual lighting practice. These relationships have been determined for multiple circular sources symmetrically located at representative positions in the visual field. However, many visual environments contain sources which present areas that are relatively long and narrow, such as continuous rows of fluorescent lamps and lighting equipments. Therefore, it is desirable to establish the average BCD brightness limitations for arrangements of luminous elements which are typical of those used in lighting practice. Because of the necessity for maintaining control, a simulated or modified visual environment which is representative of many types of lighting installations was selected as being suitable for this phase of the investigation.

The arrangement used in this part of the investigation is illustrated in Fig. 3, and corresponds to a room 40 feet long by 20 feet wide with a ceiling height of 11 feet. The physical details of this room have been projected upon a vertical plane normal to the horizontal line of vision and 5 feet from the eyes. The sources, consisting of luminous elements which are the equivalent projected area of close-mounted 8-foot fluorescent lamps, are produced by slots cut in the ceiling area with lamps mounted directly behind a diffusing material. Each complete linear source corresponds to four pairs of

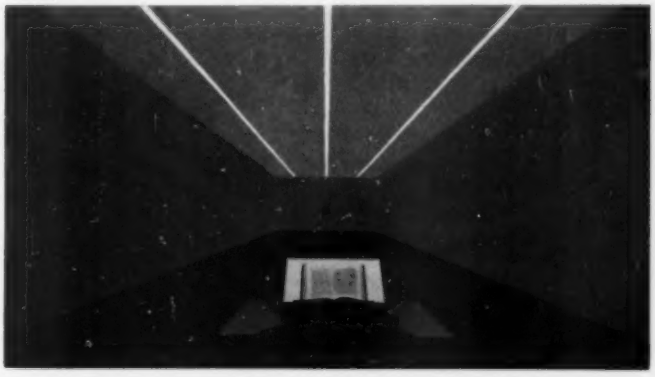

Figure 3. The experimental arrangement used for determining the BCD brightness of the elements of a simulated lighting installation. The details of a room (40 feet long by 20 feet wide with a ceiling height of 11 feet) have been projected upon a vertical plane 5 feet from the eyes of the observer. The sources consist of the equivalent projected areas of pairs of close-mounted 8-foot fluorescent lamps.

lamps placed end-to-end lengthwise in the room, each pair of lamps being considered one element of the entire source. For simplicity of control, the sources are of uniform brightness throughout their entire length. While this arrangement is not an exact duplicate of an actual lighting installation, it does contain sufficient characteristics which are representative of many visual environments. The lamps are considered to be mounted on the ceiling in such a manner that they constitute a finite area of controllable brightness. Obviously, in practice, when lamps are so mounted, a region of relatively high brightness would surround them and increase the apparent area of the source of brightness. In order to simplify the calculations and the concept, the luminous area has been made definite. Thus each complete linear source consists of four elements, each of which is an oblique or foreshortened view of a luminous area 3 inches wide by 8 feet long.

The reflectances of the ceiling, wall and floor areas were 80, 50 and 20 per cent, respectively, which correspond to those recommended as being good practice. The brightnesses of these areas were controlled independently from the brightnesses of the sources by lamps located approximately three feet in front of the vertical plane which contained the characteristic elements of the simulated room. These lamps, which were shielded from the eyes of the observer, provided brightnesses of 24, 15 and 6 footlamberts on the ceiling, wall and floor areas, respectively. Furthermore, these lamps were so placed that they permitted an unobstructed view of the entire simulated environment and their presence in no way interfered with the illusion that the observer was seated at one end of an actual 40-foot room. The brightness of the continuous rows of fluorescent lamps was superimposed upon the ceiling brightness. Thus the simulated room approximates direct lighting, as from troffers or similar equipments, but with an added means for providing some ceiling brightness. For purposes of calculation, the wall brightness was considered to be the one to which the eyes were adapted.

The purpose of this series of investigations was to determine the relative BCD brightness of the individual elements and of the entire system, and to develop a simple method of determining the probable degree of visual comfort which would be expected in a specific environment. Data regarding the entire luminous area in terms of individual areas are necessary for the ready calculation of comfortable brightness relationships in a visual environment.

The comparison method was used in these investigations to relate the brightnesses of various combinations of the elements of the simulated lighting installation to a circular source, the elements being considered the comparison-sources. The brightness of a circular test-source, located on the horizontal line of vision at the point X, Fig. 3, was adjusted by the observer until the initial momentary sensation induced alternately by the test- and comparison-sources was identical. The diameter of the circular source was 2 inches and was viewed at a distance of 56 inches, subtending a solid angle of 0.001 steradian which is approximately the same as the size used in the original investigation. The experimental variables included the brightness, area, location and the number of luminous elements which were exposed. Thus, with the basic data for circular sources, it was possible to determine the average BCD brightnesses, individually and in various combinations, of the elements of the ceiling sources.

Values of average BCD brightnesses were calculated from the equation developed from the basic data:

$$B = MPP^{0.44}\,(Q^{-0.21} - 1.28)$$

where

B = BCD brightness in footlamberts
M = Index of sensation of visual comfort
P = Position index
F = Adaptation brightness in footlamberts
Q = Solid angle subtended by the source, steradians.

The index of sensation M has been determined to be equal to 108 for average BCD.

Elements of center linear source. — In this part of the investigation the BCD brightness was determined for each element of the center linear source. Each element corresponded to one pair of simulated fluorescent lamps, Element No. 1 representing the pair which was located at the far end of the room and hence was closest to the horizontal line of vision. Similarly, Elements 2, 3 and 4 represented the second, third and fourth pairs of lamps, respectively, from the far end of the room. In Table II are summarized the physical data pertaining to the individual elements and the average BCD brightnesses as determined by the representative group of subjects for the adaptation brightness F of 15 footlamberts.

The calculated BCD brightnesses presented in Table II were obtained by substituting appropriate values of F, P and Q in the equation. M was taken as 108 for the average BCD sensation. It is seen that the observed and calculated values are in good agreement except for Element No. 4. In this case the observed BCD brightness is about 30 per cent

TABLE II.

Physical data and average BCD brightnesses in foot-lamberts of single elements of the center linear source. Each element represents one pair of simulated 8-foot fluorescent lamps.

Element	1	2	3	4
Angle to midpoint of element, degrees	11	14	19	30
Position index P (midpoint)	1.5	1.7	2.1	3.4
Projected area, sq. ft.	0.39	0.49	0.67	1.01
Solid angle Q, steradians	0.000290	0.000588	0.00149	0.00523
BCD brightness, footlamberts (observed)	2000	2200	1880	1500
BCD brightness, footlamberts (calculated)	2190	2100	1960	2120
Position index P (far point)	1.45	1.6	1.9	2.5
BCD brightness, footlamberts (re-calculated)	2130	1980	1790	1560

less than the calculated value. In the investigation of the basic relationships, it was concluded that a simple and practical equivalent for multiple sources of equal brightness and areas which are located above the line of vision is the total of the individual areas located at the position of the source closest to the line of vision. Since Element No. 4 does not present as much of a foreshortened view as do the other sources, it is a relatively long and narrow source. Thus, it can be considered as a series of contiguous smaller sources of approximately equal area and brightness. Applying the rule for multiple sources located above the line of vision, the position index for Element No. 4 for the part of its area closest to the line of vision (far point of element) is 2.5 instead of 3.4 for the mid-point of the element. The new calculated BCD brightness for this element then is 1560. Re-calculated BCD brightnesses based upon the position index P for the far point of each element are given in the last line of Table II. It is seen that there is a relatively small decrease in the BCD brightness for Elements 1, 2 and 3, primarily because of their small vertical angular extent. However, the re-calculated brightness of Element 4 agrees very well with the observed value. Therefore, the conclusion drawn from the original basic investigation is substantiated by these new data. In other words, that part of an area of a source of brightness which is closest to the line of vision exerts a greater influence upon the sensation than do more remote portions of the entire luminous area. Nevertheless, the entire area of the source of brightness must be included in the evaluation of the degree of sensation which may be evoked by the source.

Complete linear sources.—The BCD brightnesses of the complete linear sources illustrated in Fig. 3 were determined by the representative group of observers. The sources were evaluated singly and by groups to determine the relative effect of adding luminous areas in the visual field. Observed and calculated values of average BCD brightness for several combinations of complete linear sources are presented in *A* of Table III. It is seen that there is excellent agreement between the observed and calculated BCD brightnesses.

The method used for calculating these brightnesses was simple and straight-forward. Each complete linear source consisted of four elements similar to those described in Table II for the center source. Since each complete source corresponds to an extensive linear source viewed lengthwise, the projected area of, and the solid angle subtended by, each element were calculated. The summation of the solid angles for the sources is indicated in Table III. For example, for the center source, the sum of the solid angles subtended by each of the elements (Table II) is equal to 0.0076 steradian (Table III). This method, rather than adding projected areas, was used because of the considerable differences in the distances from the eye to the midpoint of each source. The total solid angle of the right-hand source was calculated in a similar manner, the lateral displacement from the line of vision being included in the determination of the projected area of each element. When two or three sources were evaluated simultaneously, the total luminous solid angle is equal to the sum of the solid angles subtended by the individual elements of each complete linear source. Thus, the right-center combination is equal to the sum of the solid angles of the elements of the right-hand and center sources. The position index P is determined by the element which is closest to the line of vision.

From the preceding it is evident that the calculation of permissible BCD brightness of a lighting installation is a relatively simple matter. Each source of the installation may be considered an element, and the solid angle subtended by the projected area of each element is readily determinable. On the average, the calculated values differ from

TABLE III.

Physical data and average BCD brightnesses in foot-lamberts of complete linear sources and of Element No. 3 of each linear source.

	Combination of Sources			
	Right Center Left	Right Center	Center	Right
A. Complete linear sources				
Solid angle Q, steradians	0.0253	0.0135	0.0076	0.0059
Position index P (Element No. 1)	1.5	1.5	1.5	1.5
BCD brightness (observed)	500	620	800	1000
BCD brightness (calculated)	530	640	820	900
B. Element No. 3 of each linear source				
Solid angle Q, steradians	0.00403	0.00276	0.00149	0.00127
Position index P	2.1	2.1	2.1	2.1
BCD brightness (observed)	1400	1550	1880	2500
BCD brightness (calculated)	1420	1560	1980	2080

the observed values by about 5 per cent, which is not considered excessive.

Single elements of each linear source. — In order to further check the method of calculating the permissible BCD brightness, the BCD brightnesses of combinations of Element No. 3 of each linear source were determined experimentally. Calculated values of BCD brightness were determined from the physical characteristics of the elements. The observed and calculated average BCD brightnesses, presented in B of Table III, are in excellent agreement. This is further evidence of the suitability of using the empirical formula developed from the basic relationships for determining the permissible average BCD brightness of a lighting installation.

It is again emphasized that the brightnesses determined experimentally in this series of investigations are *average* values and can be expected to provide an environment which is uncomfortable for half of those who may view the sources. In order to obtain a situation which will be expected to be comfortable for at least 90 per cent of the occupants of the area, the brightnesses must be reduced to one-half the average BCD values. For example, in Table III, the brightness of the three complete linear sources must be reduced to 250 footlamberts in order for most of the observers to be at the borderline between comfort and discomfort. Since the linear sources extend from about 9 to more than 40 degrees above the line of vision, the important part of the visual field is included in these evaluations and calculations. In the event that critical rather than casual seeing is involved, the line of vision usually will be below the horizontal. Therefore, sources which might be distracting would be expected to be located well above the line of vision. Hence, referring to Fig. 2, it is seen that if the brightnesses of these sources are at or near the lower BCD limit, they will not be expected to be distracting. For example, a specific source having a brightness of 1000 footlamberts and located 20 degrees above the horizontal line of vision will be near the lower BCD limit for casual seeing. If a visual task is located about 20 degrees below the horizontal, or 40 degrees below the source, the 1000-footlambert source should not be distracting for even the most sensitive worker, since the average distraction brightness is of the order of 6000 footlamberts. In fact, even if the specific source were flashing, it would be expected to be distracting for only half the workers.

It may be desirable to be able to calculate whether a specific group of sources is near the lower BCD limit or is too bright to be comfortable. In the previous paper it was tentatively concluded that if the sum of the individual M values of the individual sources of a group is not more than 150, and if the M value of any single source is less than 80, the sensation induced by the group of sources will be at or less than the average BCD sensation. Calculations based upon the individual elements of the linear sources used in this series of investigations result in individual M values of less than 80 and a total of about 220. Therefore, it appears that the original tentative value of the sum of the individual M values was low and may be increased to 220 for the average BCD sensation. For the lower BCD limit, the value would be approximately 110. This latter value appears to result in brightnesses which are consistent with current good lighting practice.

References

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2. Luckiesh, Matthew and Moss, Frank K.: *The Science of Seeing*, D. Van Nostrand Co., New York, 1937.

DISCUSSION

LELAND H. BROWN*: Last year Dr. Luckiesh and the Author reported the results of their studies on brightness limits for casual seeing. Their findings created much interest, but had limited application as most brightness problems involve conditioning areas for the handling of critical seeing task. Therefore the subsequent extension of these studies to include comfortable brightness relationships for critical seeing is so valuable that this present paper should become a classic.

Flashing sources in the visual field are so distracting in casual seeing that illuminating engineers have been prone to assume that they are equally uncomfortable where critical seeing tasks are involved. For this reason the author's finding is quite surprising that the BCD brightness for continuous and momentary exposures of a source are the same when a person is concentrating on a seeing task.

The extension of this research on critical seeing to include distraction is of great importance. The finding that a source that is on continuously must have 7½ times the brightness of a flashing source to be as distracting is very significant. It will doubtless lead to the control of flashing signs in office districts and the light from welding equipment in industrial areas, etc.

The author has been very careful to point out that the BCD brightness values are actually the geometric mean of the measured values and hence are average values that will apply to only 50 per cent of all who view the sources. However, he has also stated that if a source brightness is reduced to 50 per cent of its BCD value, the result will be comfortable for at least 90 per cent of the occupants of the areas. The only published data supporting this statement are in Table I of the 1949 paper. All other data show average values only. It would therefore be most desirable if an Appendix could be added to the paper, showing at least the maximum and minimum brightness readings of the observers in addition to the geometric mean values shown.

Lastly a word of caution should be added regarding the

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findings when the observers are doing critical seeing. Both the BCD brightness and the source brightness for distraction were taken with a fixed surround brightness of 10 footlamberts. The effect that varying the surround brightness had on the BCD brightness *for casual seeing* was reported in the 1949 paper. However, no studies have been reported of the effect of different surround brightness on the BCD brightness and distraction brightness when critical seeing is involved. Instead it has apparently been tacitly assumed that the effect of the surround brightness is the same for critical seeing as for casual seeing. Such assumptions are never justified when dealing with processes as complicated as seeing; and it is hoped that the validity of the author's assumptions may be verified in the near future by actual tests.

WARD HARRISON*: Mr. Guth's paper is very welcome, furnishing as it does additional pertinent data on the subject of direct discomfort glare. One general conclusion that seems clear from Table I is that the most critical judgment of a lighting installation is by an observer who is *not* engaged in critical seeing. Critical seeing in most occupations implies inclining one's direction of view at least 30 degrees below the horizontal, and under these circumstances one's BCD value for an overhead lighting system is considerably more liberal than when one is not engaged in critical seeing but is sitting or standing casually with his gaze somewhere near horizontal. Evaluations according to both Logan's flux analysis method and the writer's glare factor system presuppose that the observer is not engaged in critical seeing but is simply looking forward in a substantially horizontal direction. Apparently these premises are the correct ones.

The second part of the paper deals with a simulated fluorescent installation. It should be borne in mind that the lamps themselves are assumed to be above the ceiling, as in the case of troffers equipped with flat diffusing plates. The data which Mr. Guth has taken give but cold comfort to those who advocate prescribing lighting either in terms of brightness ratios or just a flat figure of footlamberts or candles per square inch. His Table II shows observed BCD values of the order of 2000 for single 8-foot units (in positions 1, 2 or 3). In Table III the BCD limit is shown to be 500 for the complete installation. There is no difference in the brightness of the units; there is no difference in their ratio with the background or the general surroundings; the only difference is that in the complete installation the exposed area of light source is increased approximately twelve times, and this requires pulling down the brightness (and the brightness ratios) by fully 4 to 1. This is a most striking illustration of the fact that no system of discomfort glare evaluation can be valid unless it gives proper weight to the area of the light source or sources within the field of view.

As to absolute values, the BCD figure of 500 seems to the writer rather severe, implying as it does that for the type of installation described one-half BCD should not exceed 250 footlamberts, and that a value as low as this is necessary to obtain 90 per cent acceptance for the installation. In view of the importance of being sure that these values are set correctly, it is suggested that this particular experiment might well be repeated in a full-scale room to insure that the results are actually the same as in the simulated interior.

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G. P. WAKEFIELD*: This paper brings to mind a recent discussion we have had with the Office Lighting Recommendation and its relation to the School Lighting Standard. Many of us believe the direct zonal brightnesses of luminaires should be consistent in the two recommendations.

After reviewing the Guth data, it is now apparent that an office lighting standard might possess different brightness limitations than a school standard due mainly to the variations in viewing angles of luminaires in large office areas as compared to relatively small classrooms.

Along this same line, it seems, as this material is developed for luminaires our recommendations may further break down to general types of luminaires. This leads us to very accurate specifications as to room size, type of luminaire and brightness.

Mr. Guth's paper may produce a brightness classification system similar to the Harrison-Meaker glare rating method. Perhaps Mr. Guth would be willing to mention the differences between the two systems.

Such basic data will eventually allow us to base our brightness recommendations on laboratory evidence of human performance and comfort. Within the direct glare zone it will be possible to approach *ideal* environmental conditions to a much greater extent than we now attain in our minimum standards. This will be substantial progress for illuminating engineers.

We should not lose sight of other factors of quality of illumination. I hope Mr. Guth does not consider "the goal of brightness relationships" as the end to quality. Mr. Guth's paper deals with the direct glare zone alone. We must not neglect the reflected glare zone in achieving human performance and comfort. After this zone has had a thorough investigation then perhaps and only then can we reduce our reflected glare zone brightness below 1000 footlamberts.

Presuming these data are correct, it will be appropriate to try them under full size conditions for proof testing by a creditable jury of illuminating engineers. If the limitations then prove satisfactory they should be accepted by the Society as a basic element of design.

In studying Table I, the low brightness indicated in line C, "Distraction, continuous exposure" at various angles of vision, it is probable that these values would be lower in equal angles to the left and right of the line of vision due to the shape of the eye. Such figures would be of undue interest to the daylighting group.

Under line D, "distraction, momentary exposure," we find values which indicate the distraction power of motion. Could this sensitivity of the retina be a defense mechanism to detect early man's enemies? Since man-eaters of yesterday were mainly ground animals would the response to motion be more sensitive in horizontal angles?

Does Mr. Guth believe that the eye when focused on a critical task with the cones of the fovea signalling their messages to the brain and simultaneously the other cones on the retina detecting distraction that normal vision is attained?

W. H. KAHLER**: In recent years practically every I.E.S. Committee concerned with lighting practice has been severely handicapped when it came to making recommendations for brightness limitations of luminaires because very little dependable data were available on the subject. This paper and its forerunners presented at the Technical Conference

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last year should prove to be a real contribution to the Society. The extensive investigations summarized in these papers represent the first coordinated study of the many variables that determine the comfort of a lighting installation.

The laboratory experiments appear to be valid and now it seems that the next step should be to check the basic data with some actual lighting installations. These checks should include direct, general diffuse, and indirect lighting systems. Both small and large rooms should be included because we often find certain equipment acceptable in small rooms but very uncomfortable when applied in a large room.

When checking installations we should keep in mind the variations in sensitivity to brightness between individuals. Too often we work only with average data and forget that people using the lighting installation will function and react as individuals rather than as an average group. The author stressed this point particularly in the first paper and suggested that "factors of safety" should be used to insure comfort for the majority of a typical group of people.

If it is found that the basic laboratory research data checks well with actual installations, this basic data should enable committees that are making recommendations for schools, offices, factories and other interiors, to specify brightness limitations that are based upon scientific backgrounds.

C. L. CROUCH*: I wish to point out what I consider a serious question about Guth's conclusions regarding the additive effects of the various luminaires in the field of view.

In Guth's test sphere a series of small portholes located at increasing angles with the axis of vision were the glare sources. It was found that there was decreasing glare effect as the angles of departure increased. If one visualizes the possibility of the portholes being so close together as to form a continuous line, then one could integrate the total glare effect as a function of the angle of departure for each small porthole. However, when Guth arrives at the conclusions as to the additive glare effects from multiple sources he states "... it was concluded that a simple and practical equivalent for multiple sources of equal brightness and areas which are located above the line of vision is the total of the individual areas located at the position of the source closest to the line of vision." By the "total of the individual areas" he means a straight arithmetic adding of the areas (or solid angle) without any weighting for off-axis decrease of glare effect. The only position effect is to apply the position index to the arithmetic sum of all the solid angles as though all were located at the position of the nearest glare source to the line of vision. This appears contradictory to the results obtained with the individual portholes. This would say that with glare sources of equal solid angle the one far away from the line of vision would be equally glare-effective to the one nearby. Thus it would appear that either the functional relationship as determined from the sphere porthole tests is wrong or the mathematical handling of multiple sources is wrong. Further careful analysis should reveal a basis for reconciliation between the two concepts.

SYLVESTER K. GUTH:** It is exceedingly gratifying to an author to have a paper received with so many complimentary and encouraging remarks. However, a number of points have been raised which require further discussion.

Mr. Brown raises the question of the validity of assuming, among other things, that the effect of surround brightness is the same for critical seeing as for casual seeing. Fully realizing the danger of making assumptions, I have tried to exercise care in extending the results of these investigations to other experimental conditions. One can never be sure of human responses to a stimulus until they have been carefully appraised. Nevertheless, from many other investigations of quality of lighting it has been learned that there appears to be a relatively orderly change in the subjective responses to various environmental conditions. Thus, the basic relationships can be used as a *guide* for determining the permissible source brightnesses for other adaptation brightnesses and for critical seeing. In general, adaptation brightnesses are of the order of the brightness levels used in these investigations. Therefore, no great error should be expected if the basic relationships are used for determining the permissible source brightnesses for casual and critical seeing.

An analysis of the observed data for the various experimental conditions indicates that the subjective differences are in substantial agreement with the original data obtained with fifty observers. Among the ten representative observers, the "low" subject selected BCD and distraction brightnesses that were about one-half the average values and the "high" subject selected brightnesses that were approximately double the average brightnesses. Since the observed data obtained with fifty subjects are more extensive and follow normal distribution, it appears entirely proper to use them for estimating the permissible brightnesses in order that a greater number of people will find the brightnesses to be comfortable. A preliminary analysis of these data has indicated that one-half the average BCD brightness should be expected to be comfortable for 90 per cent of the occupants of an area. This analysis is continuing and the results will be presented at a later date.

Mr. Harrison feels that the concept involving casual seeing is the correct one for the appraisal of comfortable brightnesses. It would seem that whether the concept of casual or critical seeing is used should depend upon the visual demands made of a worker in a specific visual environment. In many offices and industrial interiors, the line of vision is well below the horizontal practically all the time. Under these circumstances it may be entirely correct to use the brightness relationships for critical seeing. In other interiors it may be proper to use the relationships for casual seeing. In other words, just as a lighting installation should be engineered for visual requirements, its appraisal also should be based upon the visual requirements. This follows from our experience that some lighting equipments which are eminently suitable for small private offices may be unsuitable for large general offices.

Mr. Wakefield requests a brief discussion of the differences between the Harrison-Meaker glare rating method and the BCD concept. Essentially, the two approaches are similar since they both include the same four factors — the size, brightness and position of a source, and the adaptation brightness — in the appraisal of sources of brightness. The primary difference is that the index M of a sensation of visual comfort on a BCD basis is keyed to brightness, whereas the glare factor is keyed to area. Calculations by the two methods indicate that they are generally in accord and that one-half averge BCD is approximated by a glare rating of 15.

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The glare factor formula is a simplified relationship based upon judgment, experience and the data available at the time. It was an attempt to reduce to practice some of the relatively intangible brightness relationships. In his original paper, Harrison stated that the formula might need considerable modification with more complete knowledge. Extrapolation of the glare-rating method to very small sources may lead to unjustifiably high brightnesses just as the Holladay data appear to for large areas. The BCD investigations were designed to fill some of the gaps in our knowledge and resulted in a continuous relationship for large and small sources covering a wide range of sizes. The BCD formula is somewhat more complex than the glare-rating formula. However, human reaction and response are complex and it is often dangerous to oversimplify the relationships.

Ultimately, it is hoped, a single classification system will be developed which will be based upon experimental data and which will be acceptable to all. Obviously, before final acceptance, it will be necessary to experimentally check the basic data in full scale areas and to develop a simple method of making calculations. Such tests are being planned.

Mr. Wakefield wonders whether normal vision is attained when eyes are sending task and distraction stimuli simultaneously to the brain. I would like to counter this with the question — "What is normal vision?" Obviously, true "normal" vision, among other things, would include maximal visibility and maximal ease of seeing. The theoretically ideal environment would probably include a perfectly uniformly bright and extensive surround with the visual task located at its center. However, the sheer monotony of such an environment could be a distraction in itself. Thus, a suitable brightness pattern can produce a psychologically comfortable environment which will produce no measurable loss of vision. In fact, vision may be stimulated by conditions which theoretically may be distracting. Nevertheless, the visibility of possible distractions should be reduced to a minimum. These investigations give us a clue to what should be done to sources of brightness to reduce their "visibility" below the point where they will be distracting or uncomfortable.

The first paragraph of my paper should allay Mr. Wakefield's fear that I consider these investigations as being the complete answer to quality of lighting. Obviously, no part of the visual field can be ignored. Therefore, the reflected glare zone ultimately should receive as much attention and consideration as the direct glare zone.

I believe that Mr. Crouch is trying to read more into the paper than is there. At no time has it ever been intended to indicate that two equal sources located at different positions in the visual field induce equal visual sensations. What I have attempted to do is to develop a simple and logical method, based upon experimental data, for determining the probable sensation that would be induced by a group of sources of brightness. That this method, which involves the addition of the individual solid angles and a single position index, appears to have possibility is evidenced by the close agreement between observed and calculated BCD brightnesses. In the event that it is desired to use the position index as a "weighting factor," an alternate method is suggested in the last paragraph of the paper. Calculated values obtained by the two methods indicate good agreement. However, I believe that the method of adding solid angles is the simpler of the two, since it requires the determination of only one position index.

Lighting for Library Stacks

The lighting installation in the stacks of the Harrison Memorial Library, Carmel, California, was designed to provide even and adequate illumination for reading, on both a horizontal and a vertical plane — for reading titles of books on the shelf and for browsing through a book in your hand. A semicircular louver around a single fluorescent tube provides a longitudinal 30-degree shielding angle. An average of 32 footcandles is obtained on the titles of books on the shelf. Photo courtesy of Fluorescent Fixtures of California, San Francisco, California.

Night views of bank tower show the effectiveness of the new lighting installation.

Bank Tower Floodlighting

OFFICIALS of the Home Savings and Loan Bank in Youngstown, Ohio are convinced that the lighting installation in the tower of their building accomplishes the threefold purpose for which it was designed — beauty, attraction, advertising value.

Black and white photographs could never adequately illustrate the installation. A planned use of color and light is its most outstanding feature.

The sign at the base of the tower is of gold tubing. The letters are five feet in height, averaging four feet in width, with a 13-inch stroke. The sign is equipped with a flasher system operating the north and south faces together, and the east and west faces together — time approximately four seconds.

Four tiers of 150-watt reflector lamps floodlight the tower. To give the effect of graduated color of deep amber at the bottom to white at the top, lamps on the lower tiers are equipped with amber color caps, the upper tiers being without color. With the amber color caps in place, approximately 20 footcandles is obtained on the vertical surface of the tower.

Behind the clear glass on each face of the clock, 96-inch T12 lamps operating at 425 ma are spaced on 6-inch centers. The lamps are mounted a distance of two feet behind the face on a white plywood background.

Windows at the top of the tower are each equipped with a three-kilowatt mercury lamp 55 inches in length. With a light output of 120,000 lumens each, these lamps provide a beacon effect in the surrounding atmosphere.

The dome of the tower is crowned with single strips of gold tubing, following the contour of the dome.

At Christmas time, when the bank wished to change the atmosphere of the tower lighting to correspond with the spirit of the season, green color caps were used for the main area of the tower, with red on the four edges.

The bank building, with its tower of colored light, has become a landmark in Youngstown, and a source of pride to its officials.

Photographs and lighting data supplied by R. G. Zimmerman, Ohio Edison Co., Youngstown, Ohio, who designed the installation.

Effective Practice in Lighting Unusually Hazardous or Irregular Roadway Areas

By R. M. SWETLAND and J. S. LINDSAY

AS PROGRESS is made in the general practice and knowledge of effective and economical roadway illumination, an occasional pause seems warranted for the purpose of emphasizing some of the special and unusual application problems encountered in this field.

Accordingly, an attempt has been made here to assemble a few fairly well-proven methods, as well as to advance suggestions which may need further substantiation in actual practice, relative to satisfactorily solving some of these irregular roadway lighting problems. It is believed that the suggested solutions outlined in the following text are generally consistent with the principles incorporated in the "American Standard Practice of Street and Highway Lighting"[1]; although dealing with these problems in a bit more detail than is possible in such a standardized code treatise.

It is recognized that the inherent limitations of this form of presentation necessarily precludes anything approaching a complete exploration of these irregular roadway lighting problems. The hope is, however, that certain of these findings may be of practical assistance to others who may be dealing with the lighting of similar areas; and that this discussion may serve to stimulate further roadway lighting investigation — in the direction of one well-known industrial slogan "There is Always a Better Way."

I. Severe Roadway Curves and Grades

A. Curves

Problem. — "Sharp Curves Ahead." This sign is familiar to all vehicular drivers, as a warning to be prepared for hazardous conditions. It calls for concentrated attention and an alert eye on the road. These requirements are especially needed when driving at night. The placement of highway lighting equipment to secure maximum visibility on these pronounced curves deserves a careful study of application techniques.

Suggested Solution. — In lighting unusually hazardous sections of roadway, the critical placement of light sources is often as important as the selection of the light source and the specific type of luminaire and light control. In effectively lighting severe curves, the placement and spacing of luminaires should be considered as major factors.

Experience indicates that luminaires should be located on the outer edge of the curve to give the most effective pattern of pavement brightness. This places the road pavement, together with possible objects, in a direct line between the observer and the light source, thereby producing a better silhouette effect and improved visibility.

The linear spacing of units around the outside of the curve usually can be considered as a function of the radius of the curve and the "normal" distance between units on an adjacent straight portion of the roadway. Fig. 1 shows a suggested luminaire spacing in graphic form. The advised distance between units on the curve portion is determined by taking one-third the radius of the curve or the "normal" spacing, whichever is shorter.

In planning the luminaire layout on roadway curves, the first unit should be placed at approximately the center of the arc, with the additional

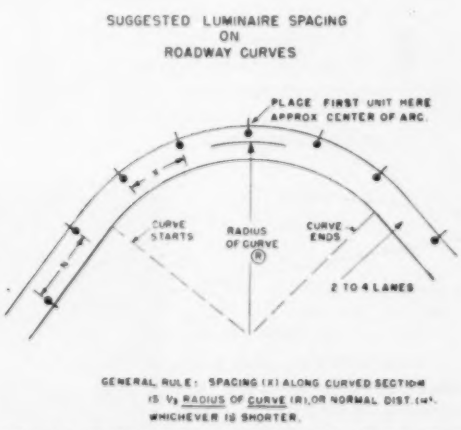


Figure 1. Typical advised application of luminaires along outside of severe curve.

A paper presented at the National Technical Conference of the Illuminating Engineering Society, Pasadena, California, August 21-24, 1950. Authors: General Electric Co., Lynn, Mass.

Figure 2. View of excellent pavement brightness uniformity resulting from proper positioning and design of luminaires.

units spaced according to the general rule given above.

The application of this method of lighting severe curves has been tested with excellent results. Fig. 2 shows a night photograph of one such installation which illustrates the uniform pattern of pavement brightness over this three-lane concrete roadway. Obstacles are easily and quickly identified as dark objects against this lighted background. Ease in detecting objects quickly is especially important in night driving where sharp curves often drastically reduce driver sight distances.

Comments.—Shorter luminaire overhang distances, two or four feet, are often sufficient on the outside of two- to three-lane-pavement curves; as compared to the advisability of a longer overhang distance on straight sections, with probably increased luminaire spacing.

When dealing with wide pavement areas (50 feet and more), carrying heavy traffic, it usually becomes necessary to position luminaires along both sides of the curve.

B. Steep Grades

Problem. — While roadway lighting presents many obvious problems, yet occasionally a condition prevails which is not recognized as a problem until after an installation is completed. Effective street lighting on a severe grade requires careful aligning of luminaires in order to avoid a possible spotty, non-uniform appearance when looking downhill, and objectionable luminaire glare when viewed in the opposite direction.

Solution. — A relatively steep grade of 10° is considered in Fig. 3. This sketch shows two methods of aligning luminaires. The first method, which is unfortunately the predominant method, mounts the units "plumb" to the pole. Obviously, this type of mounting creates a definite variation in the angle of maximum candlepower incident to uphill and downhill sides of the slope. Modern luminaires

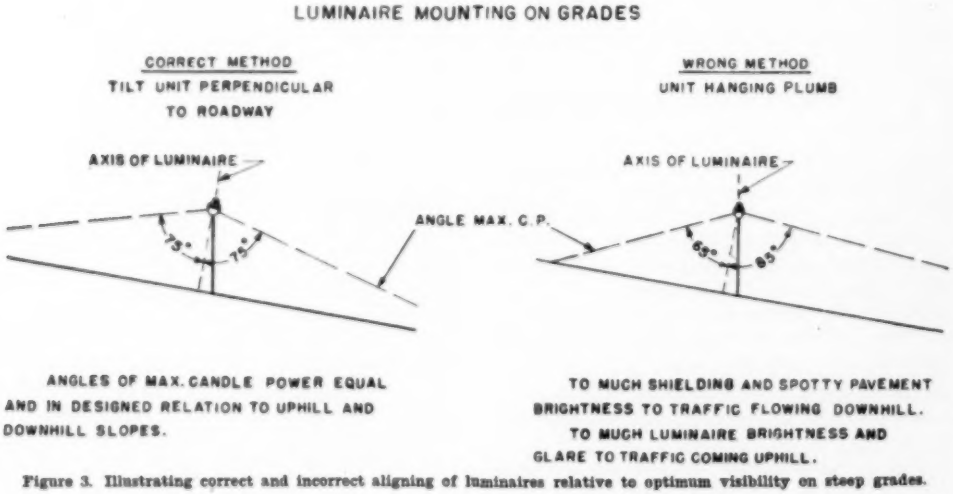

LUMINAIRE MOUNTING ON GRADES
CORRECT METHOD
TILT UNIT PERPENDICULAR TO ROADWAY
AXIS OF LUMINAIRE
ANGLE MAX. C.P.
75°
75°
ANGLES OF MAX. CANDLE POWER EQUAL AND IN DESIGNED RELATION TO UPHILL AND DOWNHILL SLOPES.
WRONG METHOD
UNIT HANGING PLUMB
AXIS OF LUMINAIRE
69°
65°
TO MUCH SHIELDING AND SPOTTY PAVEMENT BRIGHTNESS TO TRAFFIC FLOWING DOWNHILL.
TO MUCH LUMINAIRE BRIGHTNESS AND GLARE TO TRAFFIC COMING UPHILL.

Figure 3. Illustrating correct and incorrect aligning of luminaires relative to optimum visibility on steep grades.

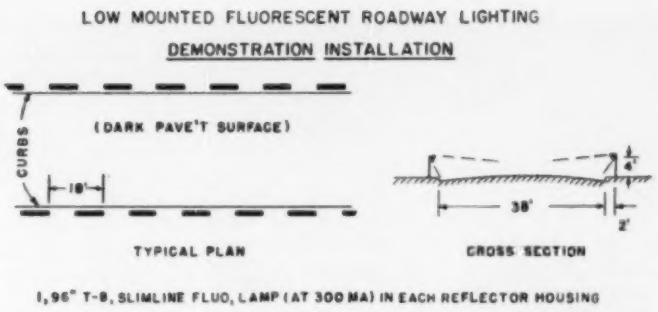


Figure 4. Application of low-mounted fluorescent units, using 96" T-8 Slimline lamps, to heavy traffic roadway.

are designed with the maximum candlepower output at a specific angle to the vertical in order to produce optimum visibility. With a "plumb" mounting on a steep grade, this design characteristic is destroyed.

In the case cited in Fig. 3, the angle of maximum candlepower was designed for 75°. This angle is decreased to an effective angle of *65°* on the uphill side. This has the effect of creating too much shielding and a spotty pavement brightness as viewed from the uphill position. Conversely, the downhill angle of maximum candlepower is increased to one of *85°* with traffic. This high angle causes too much luminaire brightness and objectionable glare to downhill observers. Thus, the resulting illumination and visibility when viewed from both directions is dissimilar and unsatisfactory.

The correct solution is also illustrated in Fig. 3, with the luminaires titled until perpendicular to the road surface. The angle of tilt between the luminaire axis and the pole axis is equal to the angle of the slope. This method of mounting permits the proper luminaire light control in accordance with its design characteristics. Uniform light distribution and comfortable seeing thus are assured to traffic flowing in both directions.

II. Low-Mounted Fluorescent Lamp Installations

Problem. — Frequently, it is desirable, or necessary, to provide adequate visibility along such areas as bridge, viaduct, and ramp roadways, through certain underpasses, and along roadways adjacent to airport runways by means of lighting equipment mounted at a three- to four-foot height and positioned along one or both sides of the roadway.

This problem is quite well known, and considerable study[2, 3] has been devoted, already, to its solution. Mention may be made that such pertinent factors as (a) luminaire glare interference, (b) satisfactory pavement brightness and visibility under all weather conditions, (c) installation and maintenance costs, and (d) dependability of lamp and system operation must receive due consideration in the planning of this type of roadway lighting.

Suggested Solution. — The use of the slimline fluorescent lamp appears to be one effective solution to such problems. These light sources possess the advantages of (a) high luminous efficiency, (b) relatively low lamp and luminaire brightness factor, (c) ready adaptability to an efficient optical system, (d) relatively long life, (e) fairly stable oper-

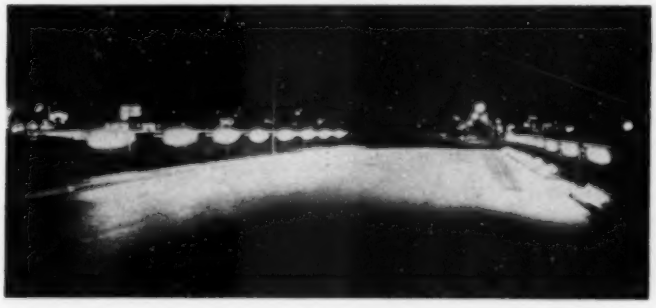


Figure 5. Visibility resulting from low-mounted fluorescent lamp application outlined in Fig. 4.

ating performance and (*f*) an advantageous linear shape.

A recent demonstration installation of 96" T-8 lamps enclosed in low-mounted fixtures along a one-way heavy traffic street in the Boston area is shown by Figs. 4 and 5.

The luminaire sections were mounted approximately four feet above the pavement level and some two feet back from the curb line. A linear spacing of approximately nine feet staggered prevailed. The pavement width is 38 feet with a well-worn black top surface.

The weatherproof reflector-housing incorporates a polished aluminum trough reflector, with clear plastic front cover. The optical system produces a maximum candlepower output at approximately 72° from nadir; with a positive cutoff and shielding of objectionable brightness above this angle. The standard cool white lamps were operated at 300 ma from two-lamp multiple ballasts.

At this nine-foot staggered spacing, approximately 4.0 footcandles calculated average horizontal illumination over the pavement was obtained, with a horizontal average along the center line of 0.85 ft-c and a center line uniformity of 1.13 to 1.0. The component of vertical illumination is an important factor in overall visibility from this type of lighting system, and ranged from a 1.4 ft-c measured average along the center line to 2.3 ft-c along a driving lane midway between the curb and the center line — on a transverse plane three feet above the pavement level.

Comments. — A consensus of qualified observer opinion stamped the visibility from this low-mounted system as quite satisfactory and adequate, even under wet pavement conditions. At this spacing, the slight shutter effect near the curbs did not appear objectionable. (Undoubtedly, a somewhat longer staggered spacing would be permissible along secondary traffic roadways with concrete pavements.) Shadows from passing vehicles were negligible. Fairly good visibility resulted with only the right-hand line of lamps burning; with a marked improvement to be expected if the pavement were concrete.

Generally, the cost of such a low-mounted system — on an equivalent visibility basis — exceeds that of a modern overhead system. However, specific requirements and conditions incident to such roadway lighting projects, often relegate the economic factor to a secondary position. Along many secondary roadways, a lower level of illumination and visibility would likely prove adequate, with a corresponding reduction in cost.

The 96" T-12 slimline lamp can be used, also, in the same luminaire employed in this installation.

III. Severe Foliage Conditions

Problem. — Heavy foliage conditions often introduce a 25-50 per cent decrease in the effectiveness of even the most modern street lighting installations. Oftimes, luminaires are so completely screened by branches and leaves that an otherwise effective lighting installation deteriorates into one of successive small "spots" of light directly under the luminaires, with hazardous dark areas between. The proper control of trees and foliage, however, may actually contribute to the effectiveness of a street lighting installation, in terms of improved comfort and visibility.

Suggested Solutions. — Careful foliage pruning, performed by experienced personnel, is often the most practical answer to this lighting problem, in areas of well-established forestation.

A suggested guide for foliage trimming is presented in Fig. 6. This sketch indicates the necessity of trimming only those branches which fall below the angle of maximum candlepower. *TH* represents the trimming height, *H* the luminaire height, and *D* the distance from the luminaire to the offending branch. The following formula is proposed for determining the correct trimming height required. This height is equal to the mounting height of the luminaire, minus one-quarter the distance from the luminaire to the branch to be trimmed. ($TH = H - \frac{1}{4}D$) (The constant "¼" is based on the co-tangent of the angle of maximum candlepower; this angle being approximately 75° in accordance with modern luminaire design.)

Such foliage trimming may shield emitted light at the higher angles, and, by reducing possible ob-

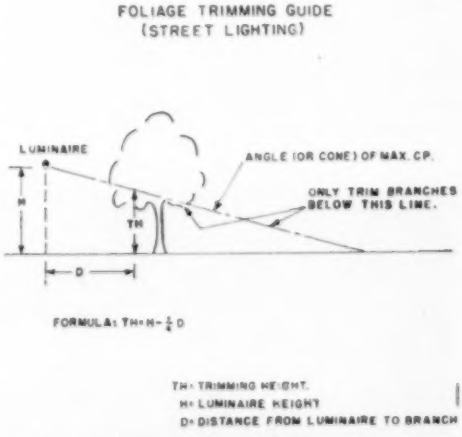


Figure 6. Suggested foliage trimming guide for street lighting installations.

Figure 7. Visibility along heavy-forested residential street resulting from combined lower height, shorter spacing and longer overhang of luminaires.

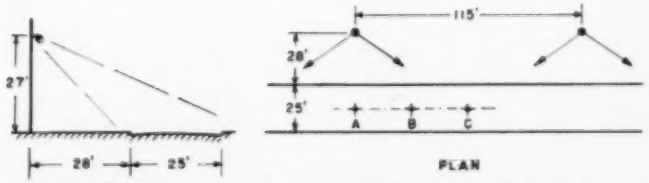
jectionable luminaire brightness, produce more comfortable and effective visibility. Furthermore, illumination levels actually may be increased with proper treee trimming in certain instances, due to the downward light reflected from the heavy foliage above.

For new lighting installations where heavy foliage prevails, one solution lies in the proper positioning of luminaires. Usually this technique involves a decreased mounting height and a relatively short linear spacing of units. It is recommended that a substantial overhang be utilized with this method. This solution may be particularly effective on residential streets, where luminaires are equipped with lamps of smaller sizes which can be operated at lower heights without causing objectionable glare.

Fig. 7 illustrates the excellent results obtained on a residential street in Chicago by applying this procedure. The units are enclosed suburban luminaires equipped with 2500 lumen lamps. A relatively low mounting height of 20 feet is utilized, an average linear spacing of 165 feet and with 12-foot brackets between intersections and a 15-foot length at the corners. Although the surrounding foliage is dense, this positioning of luminaires produces excellent pavement brightness and overall visibility.

ROADWAY LIGHTING

LUMINAIRE BACK FROM PAVEMENT EDGE



2 WAY VERTILATERAL LIGHT DISTRIBUTION; USING A 500 WATT MULTIPLE LAMP.

	ALONG CENTER LINE		
	A	B	C
HORIZ. FOOTCANDLE MEASUREMENTS	0.29	0.26	0.23
VERTICAL " "	0.38	0.39	0.25

Figure 8. Illustrating off-pavement positioning of luminaires relative to lighting of secondary traffic roads.

Figure 9. Visibility resulting from typical installation of equipment as outlined by Fig. 8.

Comments. — Along more heavily-traveled streets, meriting higher illumination levels and larger lamp sizes, good results have been obtained by using a deflector-type pendent luminaire with diffusing globe, and with the lamp filament raised slightly above the normal position — thereby producing a 55°-65° angle of maximum candlepower and improved shielding to traffic. This modified lamp position usually supplements the above-cited lower mounting height and shorter luminaire spacing.

When new streets are being planned, it is quite possible to select such tree types and such positioning with respect to the roadway, that there will be no subsequent foliage interference with a modern street lighting system. Considerable helpful information to this end is contained in a previous paper by Scanlon and Reid, entitled "Correlation of Street Lighting and Street Tree Management."[4]

IV. Positioning of Luminaires a Considerable Distance Back from Edge of Pavement

Problem. — Occasionally, local right-of-way regulations — or other inflexible factors — make it necessary to locate luminaires some 30-40 feet back from the paver Such limitations usually occur along inte n highways, often involving secondary roads where a relatively low level of illumination may suffice.

While it is quite impossible to effectively and economically illuminate a roadway under this type of handicap; yet some visibility and protection can be afforded and "a half loaf is better than none." The following proposal constitutes one fairly satisfactory answer to this problem.

Suggested Solution. — The pendent luminaire used embodied a reflector-refractor optical system, having a two-way Type I distribution with a 78° vertical angle of maximum candlepower and a pronounced lateral shielding or cutoff characteristic. Such luminaires have been used,[5] successfully, for boundary fence protective lighting; located on poles positioned some 15-20 feet inside the fence line.

Fig. 8 shows a demonstration installation of these vertilateral type luminaires, equipped with 500-watt filament lamps; mounted about 27 feet high, positioned some 115 feet linear and about 28 feet back from the edge of this well-worn black top pavement with the luminaire axis aimed at the center of the roadway.

Fig. 9 shows the resulting night visibility, under dry pavement conditions. While local fence and adjacent building proximity were not ideal, yet this demonstration proves that very acceptable visibility, for secondary traffic roadways, can be pro-

Figure 10. Daytime entrance visibility at Manhattan end of Brooklyn-Battery Tunnel. Overcast sky.

Figure 11. Appearance of tunnel portal area under sunlight conditions outside.

vided under such off-pavement limitations. Center-line measurements indicated 0.26 ft-c average horizontal, and 0.34 ft-c vertical, at pavement level.

Comments. — Obviously, optimum visibility will result from this type of installation *only* under dry conditions and with light-tinted, matt-surfaced pavements.

Again, larger lamps and closer spacing will be required, generally, from such off-pavement positioning to produce visibility at all comparable to that from properly-located luminaires overhanging the driving lane. It would appear that all influencing factors incident to such a problem should be appraised *most thoroughly*, in an attempt to find a more effective answer, before any final decision is made to install units a substantial distance back from the pavement.

V. Daytime Lighting of Tunnel and Long Underpass Entrance Sections

Problem. — This matter of effectively and economically minimizing the sudden loss of visibility as a motorist enters a straight tunnel portal section, under bright sunlight conditions immediately outside, is one of the most difficult obstacles with which the street lighting engineer must contend.

Generally, a fairly satisfactory solution to this problem is quite readily attainable in the case of urban traffic tunnels. Here, average speeds of entering vehicles are usually in the 25-35-mile range; with portal areas often shaded from continuous direct sunlight and with light-tinted tunnel lining surfaces generally prevalent.

Much more difficult is the problem at relatively short 500-800-foot tunnels on main highways, where entering speeds of 40-60 miles per hour are encountered. Frequently, such tunnel portals have a continuous exposure to direct sunlight, with often a sidewall and ceiling finish of poor reflectance. Under such conditions, a motorist suddenly plunges from an outside 2000-4000 footcandle area into a relatively "dark hole" at a speed which carries him entirely through the tunnel in from 6 to 10 seconds. Thus, insufficient time is available

Figure 12. Daytime entrance visibility at same tunnel portal shown by Fig. 11, except after installation of supplementary floodlighting.

to permit any appreciable eye-pupil accommodation toward improved visibility under this sudden splash of relative darkness. The accompanying hazard is vastly increased in the case of two-way traffic tunnels.

Suggested Remedies. — At best, only a few proven remedies can be outlined here. Each tunnel project usually imposes a specific set of conditions, necessitating careful individual study.

Fig. 10 illustrates the daytime visibility at the Manhattan portal of the new Brooklyn-Battery Tunnel. Somewhat overcast sky conditions prevailed at this time. A level of 20-25 footcandles is provided inside the portal by this double row of 72" slimline lamps at 450 ma. (This portal level graduates down to the lower level of the continuous system over an 1800-foot entrance section.) Sidewall brightness is excellent and, with the gradual curve, affords a background for an effective silhouette contrast. At this portal, entering speeds are in the 25-30-mile range. Entering visibility is reported quite adequate even under sunlight conditions — which are minimized due to surrounding buildings. (Incidentally, conditions at the Brooklyn portal include an entering vehicular speed of about 40 miles per hour with a somewhat greater exposure to direct sunlight.)

Figs. 11 and 12 illustrate the "before and after" daytime visibility at a portal of the Liberty Tunnel, Pittsburgh, Pa. Even with about a one-footcandle illumination level (under the old lighting system) a solid dark field faces the motorist entering from sunlight conditions outside. The average entering speed is about 20 miles per hour. The ceiling-mounted floodlights, 30 in number, are equipped with 1500-watt, 1000-watt, and 500-watt lamps; providing approximately 100 footcandles near the portal, decreasing to about 20 footcandles 150 feet in from the portal.

While this treatment constitutes a fairly effective answer to the problem, likely some improvement would result if a greater percentage of light were directed toward the sidewall and ceiling areas; plus the extending of this graduated intensity over a longer entrance section, up to 500 feet.

The following suggestions were offered, recently, for improving daytime entering visibility through a 600-foot arch-type ceiling, one-way traffic tunnel on a high speed interurban parkway.

1. Maintain sidewalls and ceilings a light-tinted matt-reflecting surface.
2. Maintain a light colored paving surface.
3. Paint curb lines some distinctive contrasting color.
4. From existing ceiling floods, concentrate a higher intensity on sidewalls and ceiling; approximately 100 footcandles at portal, diminishing to 8-10 footcandles at far end.
5. Coat exterior surface of portal area some dull, low-reflecting color. (Portals are exposed to direct sunlight.)
6. Install a dark-colored pavement surface for a distance of 500 ft. outside the portal.
7. Shield same 500 ft. section outside portal from direct sunlight by means of heavy evergreen foliage.
8. Limit maximum entering speed to 30 miles per hour.

Specific local conditions incident to other tunnel projects might well influence additional remedial steps.

Comments. — A pronounced curve section immediately inside a tunnel portal provides an outer wall background which, when brightly lighted, markedly aids visibility by the silhouette effect.

Again, the admission of additional daylight into the portal by a higher funneled ceiling constitutes another effective aid in solving this visibility problem. The Jersey portal of the Lincoln Tunnel, New York, is an example.

At the Broadway Tunnel, Oakland, California, an exterior ceiling louvered structure was installed extending some 200 feet out from each entrance. The ceiling openings were so designed as to exclude all direct sunlight and, further, to produce a decrease in daylight penetration as the motorist approaches the portal, proper. This solution is fairly effective — although somewhat costly — and is limited to climates having little snow and ice.

Conclusion

The pronounced trend toward greater vehicular density and higher average speeds on our modern roadway systems renders this problem of adequate night visibility one of increasing significance — with specific attention at these hazardous points demanding top priority. We confidently believe that better solutions must, and will, be forthcoming.

The author extends sincere appreciation to the Port of New York Authority and to Messrs. Mahan, Bock, and Eddy of the General Electric Company, for helpful comments and data during the preparation of this discussion.

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DISCUSSION

G. A. TROSPER*: With reference to low mounted units in wet weather upon bridges, viaducts, etc., it seems to me that, unless the pavement surface had a high degree of diffuse reflectivity on fairly wide roadways, there would be considerable dark areas along the center. The dark areas would conceal hazardous holes in the pavement, the sides of which would not get sufficient illumination to become visible to the oncoming drivers.

I think there would be a limit to the roadway and pavement characteristics upon which this type of lighting may be installed.

I would like to ask the authors if they know of studies on the problem — one side lighting versus both side lighting. As it is now, the several factors including traffic, type of street, economics, etc., are to be considered by the engineer but which might become a problem upon which several engineers may not agree. Do you know of data which might lead to specific recommendations for various types of streets?

Tunnels. Have the authors considered the problem of sky brightness which may be encountered upon leaving a tunnel?

There is one such case in San Francisco where extreme contrast prevails on certain hazy, bright days. Fast moving cars will run up on slow moving vehicles and others may run along the raised center strip because the drivers have difficulty in orienting their position in relation to their position in the tunnel. No amount of artificial lighting appears successful if within economical limits. Several attempts have been made to paint the center strip or the spot light on this strip or to install small perpendicular flags so that drivers can see their position.

There is another tunnel in Oakland across San Francisco Bay which has been in operation for a number of years. This tunnel has a large grill work containing overhead louvers constructed at each end. These louvers do a remarkable job of breaking up sunlight and sky glare and graduating the illumination on entering or leaving the tunnel. However, the speed of traffic has now increased to such an extent that either an extension of this superstructure or some other solution is required to bring about a complete solution of the problem.

Suggested Solution. — If a large baffle or wall were constructed across the roadway allowing clearance under it, about 100 feet out from the tunnel, it would cut off most of the glare from the bright sky. If this baffle were painted a flat shade of buff or other suitable color, that would be within brightness limits under direct sunlight, it would reflect a very useful amount of light back a considerable distance into the tunnel so that the outgoing drivers could clearly see the side walls and roadway areas.

This suggested solution is backed up by a demonstration or a condition that exists at the opposite end of the same tunnel wherein the roadway curves downward and to one side just after leaving the tunnel. The sky brightness is shielded at the upper part with foliage and the greater portion of the lower tunnel entrance by the east wall of the roadway. The concrete wall is painted a light buff. On Sunday afternoons, when the sun hits this wall, a considerable amount of light is reflected back into the tunnel for 200 to 300 feet and there is no discomfort in driving out into the sunshine at the south end of the tunnel. There is sufficient light to see the shape of the tunnel, the walls, the center strip, and the line markings on the roadway.

Several attempts have been made to design lighting for this tunnel that would permit motorists to pass through at speeds in excess of 45 miles per hour, their eyes quickly becoming adapted, but the cost, not only of the installation but of the operation, appears to be above economical limits. It seems that treatment as suggested above is one answer.

*Pacific Gas & Electric Co., San Francisco, Calif.

R. M. SWETLAND and J. S. LINDSAY*: Mr. Trosper's interesting discussion on these pertinent problems relative to effectively lighting unusual roadway areas is both appreciated and stimulating.

With reference to low-mounted fluorescent luminaires and wet pavement surfaces, the authors' experience with pavement widths of approximately 40 feet indicates no objectionable nor hazardous dark area along the center of such roadways; using the type of luminaire and advised positioning described in the paper — despite black-top surfaces. Obviously, improved pavement brightness and visibility should result from more favorable light-tinted diffuse surfaces.

It is believed that one-way traffic, on concrete pavements up to 40 feet in width, can be assured of fairly satisfactory visibility by a one-side positioning of fluorescent low-mounted units of proper design. (Even under these conditions, however, a both-side positioning is preferable.) With wider black-top pavements and 2-way traffic, both-side positioning is definitely required.

As implied in this paper, the low-mounted fluorescent lighting system is not advocated as a first choice in producing maximum over-all roadway visibility, but rather as a fairly effective expediency.

Mr. Trosper further discusses this interesting, though possibly somewhat unusual, instance of a pronounced loss of driver visibility due to excessive sky-brightness contrast upon *leaving* a traffic tunnel. (In practically all traffic tunnel and long underpass projects with which the authors are familiar, there is practically no hazardous loss of visibility upon leaving these tunnel portals. This fact seems consistent with — and largely due to — the more rapid eye adaptation and accommodation in passing from dark to bright areas, as contrasted to the reverse procedure of sudden bright to dark transition.)

The suggested use of an overhead baffle surface beyond the tunnel exit seems to us to possess maximum merit in the shielding and minimizing of objectionable direct sunlight and sky brightness to exit traffic. Utilizing such a baffle as a reflecting surface to project daylight some distance back into the tunnel proper, against on-coming traffic, would seem to merit most thoughtful consideration relative to any specific set of conditions. The danger, here, would appear to be the possibility of too much brightness and glare toward on-coming exit traffic, thus tending to defeat the primary objective.

The authors believe, however, that more thought and experimentation should be given to the possibility of projecting daylight into an entrance portal — *in the direction of* one-way entering traffic — by means of some modified heliostat reflecting surfaces. Such a procedure, if economically reasonable, conceivably might prove considerably more effective than many methods now in use, based on artificial illumination. Again, the authors greatly appreciate Mr. Trosper's interest.

*Authors.

Lighting a Masonic Assembly Room

LIGHTING OBJECTIVE: To provide general lighting for masonic ceremonies.

Installation at Westgate Masonic Lodge
1308 So. New Hampshire, Los Angeles, California.

General Information: This lodge room measures 45 feet by 65 feet. Ceiling height is 33 feet. The rug is primarily tan in color, the walls are cream, and the ceiling is decorated in gold.

Installation: General lighting is provided by ten Rambusch Downlights recessed in the ceiling. These each contain a 300-watt lamp above a 5-inch aperture in the decorative paneling. Additional illumination comes from 300-watt reflector lamps installed in indirect wall urns as shown in Fig. 2. All lamps are controlled by dimmers. The average general illumination can be varied from zero to seven footcandles. (Supplementary illumination is available over the podium, and a narrow beam spotlight in the ceiling illuminates the central altar during the ritual.) Brightnesses are as follows:

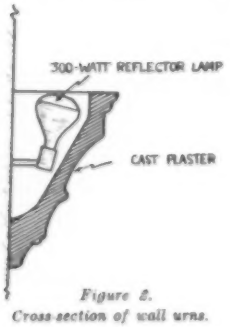

Figure 2.
Cross-section of wall urns.

rug	0.9 footlamberts
ceiling	0.9 to 1.2 footlamberts
walls	
back	0.45 to 1.1 footlamberts
side	0.3 to 0.8 footlamberts
niches	5.0 to 35.0 footlamberts

Lighting data submitted by the Illuminating Engineering Unit, Department of Water and Power, City of Los Angeles as an illustration of good lighting practice and to aid in the design of similar installations.

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Temperature Problems in Street Lighting Luminaires

By R. W. LOEHR

EQUIPMENT failures resulting from high temperatures encountered in street lighting luminaires have always presented serious problems to municipal and utility operating departments. Some of the troubles have been due to questionable equipment design and poor installation practices. However, most of the problems may be attributed to operating conditions that are peculiar to series circuits in general and high current (20-ampere) series circuits in particular.

This paper presents an analysis of some of these problems and the manner in which they have been solved, or the steps that have been taken to date in an effort to reach a solution.

Lamp Failures Due to Heat Concentration on Vital Lamp Parts

Pendent type street lighting luminaires as we know them today have been in use for approximately 15 years. They are generally recognized as reliable, trouble-free devices providing excellent light distribution characteristics. However, in some of the first designs placed on the market, short lamp life was experienced due to excessive concentration of reflected energy on vital lamp parts. Fig. 1 illustrates a particular design in which lamp failures were caused by concentration of energy on the lamp press.

The result of such a concentration was to soften the glass in the press, often permitting the filament support wires to break loose and the seal to be destroyed.

This condition was minimized by incorporating a series of longitudinal offsets in the reflector contour above that portion of the reflector from which the main beam is directed. See Fig. 2.

These offsets were arranged to direct the reflected energy around instead of through the vital lamp parts.

As mercury lamps came into increased usage, it became apparent that these offsets contributed to luminaire efficiency by redirecting a considerable portion of the reflected light around the arc stream. Also, it was found that the offsets made it possible to change the lateral width of the light distribution pattern at various vertical angles even though most of the reflected light passed through approximately the same conical zone of the refracting glassware.

Because of one or more of the above reasons, the use of offset or fluted reflectors is now standard with most manufacturers of this type of equipment, and the problem of heat concentration on vital lamp parts appears to have been solved. Moreover, oval shaped reflectors are being used in increasing volume. Such reflectors direct the reflected energy so that a substantial per cent actually clears the outer glass bulb as well as the internal parts of the lamp.

Cable Failures Due to High Operating Temperatures

Street lighting service has always imposed severe operating conditions on the conductors used to supply the luminaire. In recent years the requirements have become more severe because of trends toward:

1. Inner wiring through pipe brackets
2. Use of larger lamps
3. Elimination of insulating transformers

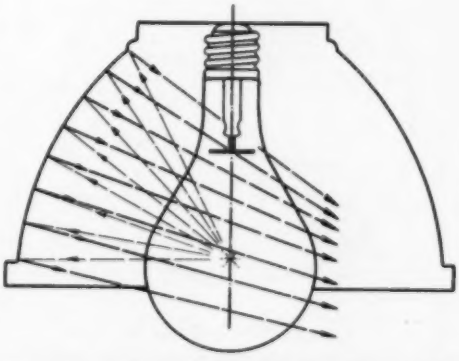


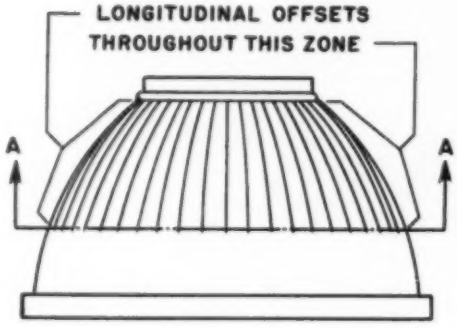
Figure 1. Ray-Trace diagram showing concentration of reflected energy on lamp press.

A paper presented at the National Technical Conference of the Illuminating Engineering Society, Pasadena, California, August 21-24, 1950. Author: Westinghouse Electric Corp., Cleveland, Ohio.

When inner wiring is employed on straight series circuits, the supply conductor insulation must be capable of withstanding operating voltages, to ground, up to approximately 5000 volts, under relatively severe moisture conditions and at high temperatures . Fig. 3 illustrates typical insulation temperatures encountered in side-mounted, inner-wired luminaires when cable insulation is carried direct to the receptacle terminals.

Temperature rises up to approximately 80°C are not uncommon when 10,000 lumen lamps are used, and rises up to approximately 60°C may be expected with 6000 lumen lamps. In the past, heat-resistant rubber was considered the best type of insulation available for this application. The upper temperature limit for this class of insulation is 75°C.

The logical answer to this problem was to pro-



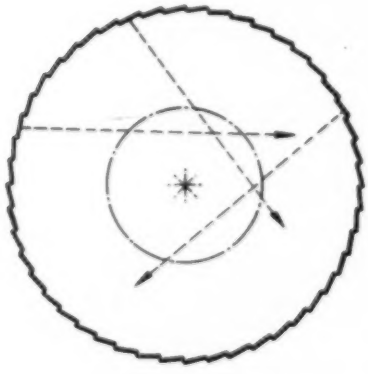


Figure 2. Ray-Trace diagram illustrating modification of reflector to eliminate concentration of energy on vital lamp parts.

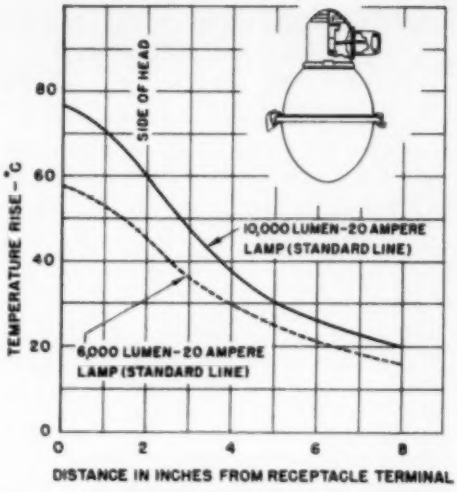


Figure 3. Cable insulation temperatures in side-mounted, inner-wired luminaire.

vide an insulating bushing of high voltage porcelain, extending through the critical zone. This type of arrangement, known to the industry as a "Heat Barrier" or "Heat Stopper" construction has received wide acceptance. A typical design is illustrated in Fig. 4.

Fig. 5 indicates the range of cable temperatures encountered when the heat barrier construction is used.

Since the introduction of the heat barrier, new, high-temperature, cable insulation materials have been announced. One of the latest of these is a silastic insulated cable with glass braid. Cable of this nature may eventually replace the heat barrier construction, but at the present time the cost of such cable is a least double that of similar cable with heat-resistant rubber insulation. Cable of this nature probably will be used to some extent for inner wiring of top mounted luminaires. One manufacturer has offered a porcelain heat barrier for use in top mounted luminaires, but such a device is somewhat more complex than the bushing used in side-mounted luminaires.

Gasketing Problems

Operating departments always have considered gaskets an evil, to be tolerated only when absolutely necessary. This attitude is largely the result of failures of gasket materials and adhesives due to temperature and moisture conditions encountered in service. Gaskets once were considered essential at junctions between reflector and head, glassware

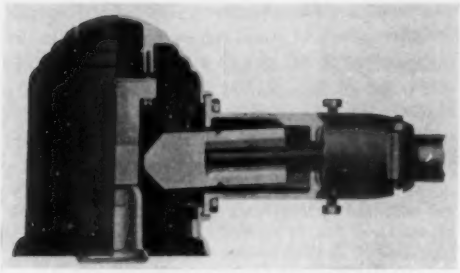


Figure 4. Typical heat barrier construction.

and reflector, or glassware holding ring and glassware or reflector. Most modern pendent luminaires with rigidly attached glassware have been designed to eliminate all gaskets of the type referred to above. In luminaires with hinged construction a single gasket generally is employed between glassware and reflector.

Most gaskets used today are of a good grade of wool felt or asbestos. The thermal properties of asbestos are well known. Some types of wool felts also have been found to have excellent heat resistance.

Greatly improved adhesives have appeared on the market in recent years. In addition, numerous schemes have been worked out for mechanical attachment of gaskets.

Gasketing has ceased to be a major source of trouble, partially because of improved gasketing materials and methods of attachment and partially because of extensive efforts to eliminate all nonessential gaskets.

Socket and Receptacle Failures

Failures under Normal Operating Conditions.— Failures of series sockets and receptacles continue to plague many operating departments. These failures appear in various forms, but most may be attributed to one or more of the following causes:

1. Use of component parts that are unsuitable for the operating temperatures encountered in service.
2. Use of sockets and receptacles that are in poor condition at time of installation on 20-ampere circuits.
3. Failure of film cutouts to break down at time of lamp failure.
4. Development of high temperatures by film cutouts following breakdown.
5. Abnormal lamp failures.

The need for an adequate margin of safety in the thermal capacity of sockets and receptacles is recognized in a recently published EEI-NEMA specification.[1] This specification stipulates that "Current carrying parts of series sockets and receptacles shall be capable of carrying 20 amperes continuously" and that "all metal parts of series sockets and receptacles shall be suitable for continuous operation at 200°C."

Series sockets with cold molded plastic bodies were introduced about twenty years ago. This construction was received with great enthusiasm at first because of the promises of reduced socket breakage from handling. However, it soon was recognized that the plastic materials used were subject to considerable shrinkage due to heat and that the sockets soon failed in service. Plastic materials used for socket bodies today are far superior to those used originally, but still must be limited as to usage.

This limitation is recognized in the new specification through inclusion of two classes of socket bodies; a "medium impact-strength, high temperature" socket body (porcelain) "for general use" and a "High impact-strength, limited temperature" socket body (plastic) "primarily for use with open type luminaires, with lamps of 200 watts or less." The specification stipulates that "Series sockets having medium impact-strength high temperature bodies shall withstand a continuous operating temperature of 200°C, and that "Series sockets having high impact-strength limited temperature bodies shall withstand a continuous operating temperature of 150°C."

In an attempt to check the adequacy of the specification, temperature measurements were made throughout the life of 15,000-lumen, 20-ampere lamps operating in typical pendent luminaires normally used with lamps of this size. The results of this test are presented graphically in Fig. 6.

The lamp base temperature actually was measured at the junction of the lamp bulb and base and is somewhat above the temperature of the

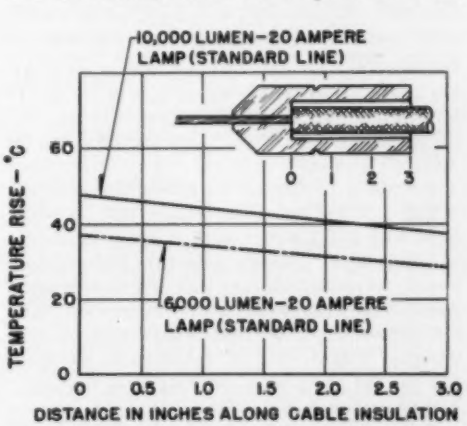


Figure 5. Cable insulation temperatures in side-mounted, inner-wired luminaire with heat barrier construction.

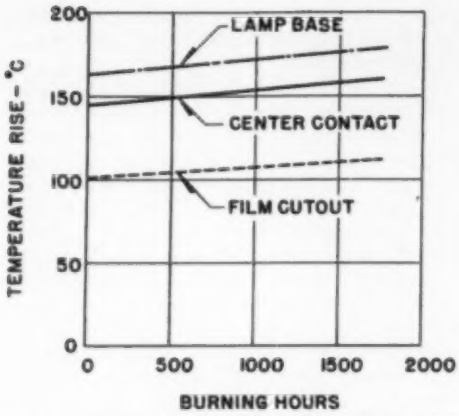


Figure 6. Variation in temperatures of lamp and socket parts throughout life of lamp. (15,000-lumen—20-ampere standard line lamp in enclosed pendent luminaire.)

socket shell. Thus, the results of this test indicate that the requirements of the specification should be adequate and that equipment meeting these requirements should stand up in a satisfactory manner under normal service conditions. The 200°C figure probably is higher than absolutely necessary for socket prongs and receptacle clips.

Some preliminary test work has been carried out in an effort to check compliance of present sockets and receptacles with the specification. Assembled sockets and receptacles were operated continuously in an oven at 200°C while carrying 20 amperes.

In one set of receptacles tested, the reinforcing springs were made of phosphor bronze. The other set of receptacles tested was made up with reinforcing springs of Type 302 stainless steel. The assemblies were checked at 100-hour intervals for compliance with the portion of the specification requiring that:

> The contact spring tension shall be such that a load of 15-25 lbs. will be required to pull a socket, having a $\frac{7}{64}$" spacer between the faces of the socket prongs, from the receptacle.

The results of this test are presented graphically in Fig. 7. These data alone indicate that the receptacles with stainless steel reinforcing springs should be satisfactory. Actually, before the test was completed, the contact clips of both sets of receptacles failed to close when the socket was removed. This condition was first observed on the receptacles with phosphor bronze reinforcing springs at 200 hours and on the receptacles with stainless steel reinforcing springs at 400 hours.

This series of tests is being continued using various receptacle spring materials, and is being expanded to include several variations in receptacle design.

Failures Due to Abnormal Lamp Failures.—Up to this point all questions of performance have been considered in the light of normal operating conditions. Actually, much of the trouble experienced in the field may be attributed to abnormal conditions.

Occasionally, high wattage incandescent lamps are observed to burn with an intense blue color for periods ranging from a few minutes to several weeks prior to burnout. An inspection of one of these lamps will disclose that the inside of the bulb is coated with a blue tungsten oxide deposit. Cases of this type result from lamp leakage or release of moisture from the glass due to over-heating and are normally found among long life lamps. However, the leakage condition can be produced by water cracks resulting from luminaire thread leakage.

TABLE I.—Comparison of Lamp and Socket Temperatures Produced by Normal and Abnormal Lamps.

Test Location	Temperature Rise °C	
	Normal Lamp	Abnormal Lamp
Lamp base	179	240
Center Contact	161	305
Film Cutout	113	188

Tests were conducted in an effort to determine the effect of this abnormal lamp condition on sockets and receptacles. Typical temperature data from these tests are set forth in Table I.

The high temperatures encountered with the Abnormal Lamps are due primarily to the absorption of energy by the coated bulb wall. In addition, the

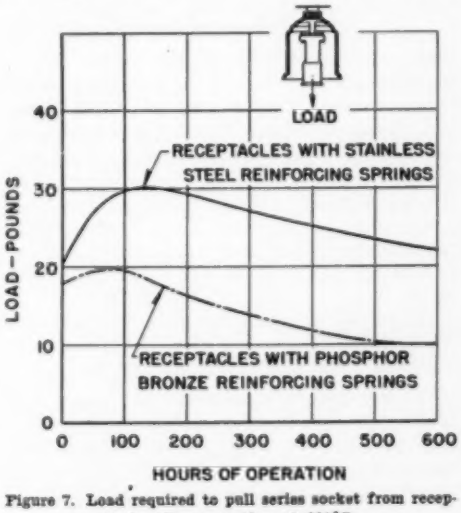


Figure 7. Load required to pull series socket from receptacle after operation at 200°C.

lamp wattage may increase as much as 10 per cent during a period of several hours just prior to burnout. The temperatures due to the abnormal lamp condition are high enough to anneal the metal parts of a socket and receptacle. The high wattage at the time of burnout makes the situation worse.

Failures Due to Faulty Film Cutout Performance. —The lowly film cutout is responsible for a high percentage of all socket and receptacle failures reported. Approximately 5,000,000 film cutouts are used in this country each year, but few people realize the full importance of correct film cutout operation.

Socket and receptacle failures can be caused by two types of faulty film cutout operation:

1. Failure of the film cutout to break down following a hot filament failure.
2. Development of excessive temperatures within the film cutout following failure.

The first of the above points is often overlooked. In the past, the common assumption has been that the open circuit voltage of the constant current transformer was available to break down the film cutout following lamp failure. Actually, in the event of a hot filament failure, momentary peaks of substantial magnitude may occur, but a film cutout must be an extremely sensitive device to function properly on these transient peaks. If an arc develops in the lamp following the filament failure, there is little increase in voltage across the film cutout until the arc travels well back into the lamp base. The net result is the establishment of an arc between the center contact of the socket and the lamp base, ending in destruction of the socket.

Tests conducted by an independent testing laboratory some years ago indicated that socket temperatures produced by ruptured cutouts on a 20-ampere series circuit after two hours continuous operation may run as high as 300°C, a figure well above the 200°C limit for which series sockets and receptacles are designed.

The results of a recent series of tests of this same nature are shown in Fig. 8. In these tests a 10,000-lumen, 20-ampere lamp was operated from a 6.6-20 ampere insulating transformer. The lamp was operated within a standard pendent type luminaire using a series socket without short circuiting bar. For each test the luminaire was allowed to operate normally until the socket parts reached a stable operating temperature. The globe was then opened just long enough to permit backing the lamp out of the socket and interrupting the circuit. A continuous recording of temperature was made throughout each test.

Considerable progress has been made by the industry toward the solution of temperature problems encountered in streetlighting operation. However, much additional work will be required before the questions regarding socket, receptacle and film cutout operation are settled in a satisfactory manner.

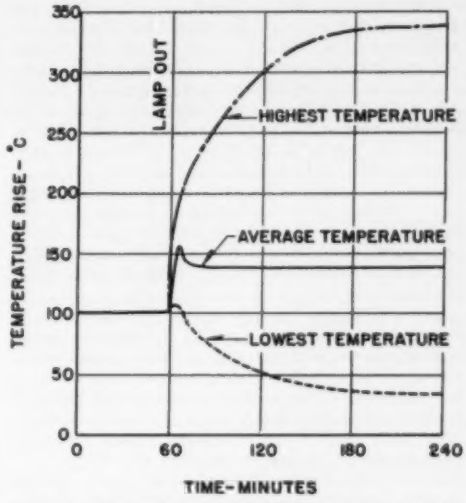


Figure 8. Temperature of socket prongs following lamp failures on 20-ampere circuit.

In conclusion, the author gratefully acknowledges the assistance given by his associates, Mr. M. R. Anderson and Mr. M. G. Morgan. He also wishes to thank Mr. W. A. Pennow for guidance in preparation of this manuscript.

References

1. Specification #TDJ-136: "Specification for Streetlighting Equipment — Series Sockets and Series Socket Receptacle," Edison Electric Institute, 420 Lexington Avenue, New York City, 1950.

2. NEMA Publication: "Specifications for Streetlighting Equipment — Series Sockets and Series Socket Receptacle," National Electric Manufacturers Association, 155 East 44th Street, New York City, 1950.

DISCUSSION

W. A. ZANDER and R. J. PALMER*: Pursuant to your request, both Mr. Zander and myself have reviewed this paper. We have found it interesting and generally comprehensive.

At the outset, however, it should be pointed out that Mr. Loehr's reference to E.E.I. specification TDJ-136 may be in error. It is expected that this specification will be published shortly, but as of this date, such is not believed to be the case.

In connection with the effect of heat on the insulation of lamp supply conductors, The Detroit Edison Company several years ago adopted the practice of using a special fixture wire or cable when lamp supply wiring is carried through bracket members. This fixture wire consists of a suitable length of No. 8 stranded duplex conductor to which are added 24" lengths of flexible stranded asbestos insulated

*Detroit Edison Co., Detroit, Mich.

tails that serve in the high temperature region. This has proven very satisfactory for use with all top mounted luminaires.

In the matter of gasketing, we are looking for the time when gaskets may be dispensed with, particularly in connection with detachable glassware. One of our more critical problems, however, has been in the fit of some glassware holders resulting in a compounding of stresses between hardened gaskets and glassware. This has been further complicated by tolerances in the fitting dimensions of glassware itself. The glassware, pendent type, develops maximum thermal stresses in the region of its holder and in several instances the combination of localized gasket, globe holder, and thermal stresses has resulted in hazardous glassware breakage in the field.

One of the causes found for series socket and receptacle failure, especially receptacle failure, has been in designs that incorporate relatively long assembly screws passing through porcelain bodies. Brass or bronze screws used in this service will have a net expansion or contraction in excess of that for porcelain of as much as .002" per inch of length as a result of the normal temperature change between on and off periods for the luminaire. In the event that receptacle circuit continuity depends on the tightness of such assembly bolts, any loosening of same will encourage the development of high resistance points in this receptacle circuit which will further increase localized heating. Such heating usually occurs near the point of maximum bending moment stresses for the contacts and springs.

Referring again to the E.E.I. specification No. TDJ-136 it might also be well to point out that in addition to the contact spring tension feature, this specification also establishes fitting dimensions and their tolerances for the mating of series socket prongs and receptacle contacts.

O. W. HOLDEN*: This paper is of real interest to those who maintain street lighting systems because with the trend toward larger lamps, new temperature problems have developed in operation.

The following comments are based on experiences in Los Angeles.

The introduction of the enclosed reflector did not present much of a problem with the smaller lamps and the offset surface did not have much appeal to the user until the prevailing lamp sizes were raised.

The use of the barrier has proved very effective in service.

The use of asbestos gaskets mechanically attached has proved so satisfactory that this method is now specified. Wool is subject to insect attack and packs under heat conditions. Adhesives are not permanently effective.

Sockets and receptacles are subject to considerable trouble from heating as described by the author. Care must be exercised in choosing adequate equipment for the larger lamp size installations. Receptacles are subject to additional heating if the conductor attachments are not carefully and securely made. Socket replacements are numerous and mostly due to damage from heating or from arcing at the lamp tip contact. Sockets should be provided with a very sure locking device to prevent lamp loosening from vibration or temperature cycling.

It has been noticed that on series circuits supplied from small constant current transformers, the film cut-outs often fail to break down with a lamp burn-out because the voltage is not sufficiently high.

The author might state whether the remarks under "Failures due to Abnormal Lamp Failures" apply to both series and multiple incandescent lamps or to only one type.

*Bureau of Power and Light, City of Los Angeles.

H. J. FLAHERTY*: Mr. Loehr's paper is an excellent presentation of a subject which has been given attention by both manufacturers and users of street lighting luminaires over a period of time.

Protection of insulation on supply conductors falls into three broad classifications:

1. Heat resisting insulation
2. Insulating bushings
3. Additive insulation

Heat resisting cable, adequate to withstand temperatures from the larger lamps of 10,000, 15,000 and 25,000 lumen series lamps in pendent luminaires, have been slow in their development although they have a field of application. New materials, such as those of the Silicone family, hold promise for the future. From the user's standpoint, heat resisting insulations would be ideal if economic considerations are met.

Porcelain bushings, whether of the "heat-barrier" or external terminal types, in effect provide protection by keeping the cable insulation remote from the high temperature areas. As such, they effectively overcome the problem and can be applied to many luminaires.

A number of users have resorted to glass cloth tapes which can be applied over that portion of the cable insulation subjected to temperatures above its rating. Such tapes have adhesive backings, making the job of taping a relatively simple one. They are available in materials that will not volatilize and thus will not cause objectionable deposits on reflecting surfaces or on enclosing glassware. With high dielectric strengths in excess of 1000 volts per layer, the insulation can be built up to desired values while holding the cable insulation in place so that even if this deteriorates in time, the benefit of the space factor is still retained.

Such tapes, already in service with 25,000 lumen lamps in pendent fixtures, permit the use of moderate cost cable and so can be considered an alternate to the other means described in the protection against high operating temperatures. Consideration should be given not only to normal conditions, but also to those described under "Failures due to abnormal Lamp Failures." Excessive temperatures given for lamps, bases and cutouts are also present in other portions of the luminaire, including the cable insulation. Although of a temporary nature, the data show they can persist for a time sufficient to have harmful effects.

Although the tendency has been away from the use of painted luminaires and the maintenance associated with repainting, there are areas where corrosion of aluminum is a factor and the protection of external surfaces then becomes desirable. The high temperatures on reflector surfaces impose a severe duty on ordinary paints. One solution appears to be the use of Silicone paints with their inherent resistance to high temperatures. Although such paints are applicable to luminaires quite generally, it must be recognized that certain parts of luminaires are more vulnerable to corrosion than others. Cast parts such as globe-holders, with their associated hinges and latches, are in this category. The elimination of these parts in the "spun-sealed" construction wherein the reflectors are factory spun directly to the enclosing glassware, not only obviates the use of gaskets, but also makes possible the complete protection of this seal against corrosion by complete coverage of all external surfaces by paints such as those of the silicone family.

*General Electric Company, West Lynn, Mass.

R. W. LOEHR*: Messrs. Zander and Palmer suggest that the writer may be in error in referring to a "recently published" EEI specification TDJ-136. A check indicates that neither the EEI nor the NEMA specification has actually been published to date, but that they have been cleared for publication and should be available in the near future.

Thousands of luminaires, employing a detachable band for clamping the glassware directly to the reflector without use of a gasket have been produced. This type of construction does set up strains in the glassware, but to date actual field experience indicates very satisfactory performance with little glassware breakage.

The receptacle screws referred to by Messrs. Zander and Palmer do loosen up in service. This is due to the fact that they are subjected to considerable strain by the force exerted on the receptacle springs. Tests have shown that these screws elongate enough to cause trouble even when lengths are comparatively short. Cast and extruded terminal sections are also deformed in a similar manner. Improved designs and proper selection of materials will be required to overcome this source of trouble.

Mr. Holden emphasizes the fact that even though equipment is right from a design standpoint, it must be installed properly if trouble-free service is to be realized. It is important that conductor attachments be made securely. It is equally important that lamps be fully engaged in the socket to insure adequate center contact pressure.

Mr. Holden suggests that film cutouts often fail to break down because the available transformer voltage is not sufficiently high. The author's experience has been that the trouble is due more often to the fact that a destructive arc strikes within the lamp before the film cutout breaks down.

In reply to Mr. Holden's question: the abnormal lamp failures are more prevalent and certainly more serious in series lamps. This is due to the rise in wattage throughout life for the series lamp.

Mr. Flaherty provides some excellent supplementary information on protection of supply conductor insulation. Further information of this type is always of benefit to both the manufacturer and the user.

As Mr. Flaherty indicates, the trend has been away from painted luminaires. This trend has been due largely to difficulties experienced in securing good paint adhesion to the aluminum reflectors. Perhaps silicone paints will come into increased usage for street-lighting equipment; however, for most applications, unpainted equipment has held up in a very satisfactory manner. The various attachment members, provided to facilitate servicing of equipment in the field, have been greatly improved in recent years and designs are available that will provide many years of dependable, trouble-free operation.

The author expresses sincere thanks to all those offering discussions on the paper. The degree of concurrent opinion was not unexpected, since the paper was prompted by field reports of trouble and suggestions for improvements of equipment. Continued cooperative efforts between operating companies and manufacturers toward a solution of the problems presented will result in improved design and a reduction of field troubles.

*Author.

Lighting for a Super Market

Lighting was designed to suit the various needs of a giant shopping center at the Consumers Market, Tucson, Arizona. The store, although primarily a food shop, also has a beauty salon, prescription counter and soda fountain. A level of 50 footcandles is distributed uniformly over the merchandise, permitting a clear view of the displays. In the grocery department, eight rows of louvered fluorescent luminaires, are spaced 15 feet apart. Each luminaire contains four 40-watt warmtone fluorescent lamps. In other sections, two- and four-lamp shallow fluorescent troffer units with louver-type shielding provide recessed lighting. Photo courtesy of Sylvania Electric Products, Inc.

European Lighting Practices

Louvers of interesting design are used in the suspended canopy which follows the line of the sales counter at Dolcis Shoe Shop, Leicester Square, London (above). Fluorescent lamps are combined with filament spots to give highlight points over the counter.

Dolcis' Princess Department, Oxford Street, is of interest because of the charming coordination of its appointments (right). A suspended ceiling of fire-proof fabric covers conduits and service pipes. Custom-built tubing is employed in the central cove, supplemented by filament lighting in ceiling downlights, directed spots and table lamps. Architect for these two installations: Ellis Somake, F.R.I.B.A., London.

At the Swiss National Tourist Office (left) the custom-built trough fittings gain lightness and interest by the simple device of vertical slits. Architects: Alfred Roth, BSA/SIA, Zurich and T. P. Bennett and Son, London.

Photographs and data were supplied by A. H. Olson, Managing Director, Courtney Pope, Ltd., 341 Seven Sisters Road, Tottenham, London, England.

Measurement of Visibility

Visibility, a Measurable Quality of a Seeing Task

By DR. C. L. COTTRELL

Visibility is considered as a component factor of a seeing task. The definition and measurement of visibility in terms of previously described methods are briefly reviewed, and a modified method of measurement based upon the contrast threshold is reported. An instrument called the contrast-brightness threshold meter is described, and results of measurements on a variety of visual targets are compared on the same targets. Conclusions are presented which seem to indicate advantages in the use of the contrast-brightness threshold meter over the L-M meter in obtaining threshold curves for a useful range of background brightnesses of a particular seeing task. It is not concluded that threshold data are enough in general, upon which to prescribe levels of illumination for desired performance rates; but threshold data may aid in determining the lighting levels required for good discernibility.

THE TERM visibility is used here to mean that special quality of a seeing task which depends upon a combination of the brightness-contrast, the subtended angular size of the detail, the brightness of the background, and the time of observation. Brightness-contrast is used here to mean the ratio of the difference between the brightnesses of the background and of the detail, to the brightness of the background. This visibility quality of the seeing task permits a comparison of the discernibility of one task with that of another, and is more than recognition of the presence of a visual target, but extends to a recognition of the orientation of the detail of the target as well. The definition of the term "visibility" as used in this report, is necessarily set forth here, in view of the unfortunate lack of general agreement among those who use this term.

It may be presumed that if only one of the task factors mentioned above is varied, the "visibility" of the task is also varied, but not necessarily in direct proportion. How then may visibility be specified? This has been done most frequently by determining the threshold of one or more of the above named qualities of the seeing task, and either to name the reciprocal of this threshold itself as the index of visibility; or to set up an arbitrary scale of "visibilities" based upon some selected reference task considered to be of unit visibility. One point of view expressed by Ferree and Rand[1] is that acuity alone cannot be considered a measure of visibility, unless all the other factors of a seeing task are held constant, and even then there is a no good basis for assuming a linear dependence. They then proceeded to investigate the relation between acuity as an index of visibility and the speed of perception. Their results show a lack of a definite general relationship between these two indices; though they suggest that the speed-of-perception index is a good measure of visibility. To do this experimentally outside the laboratory is not feasible, and in this study speed of perception was not considered as a practically measurable index.

Since many investigators have reported on the threshold of contrast *vs* brightness over wide ranges of the controlled parameters it was decided to consider the possibility of using this threshold as a measure of visibility. Some available published data are shown in the curves of Fig. 1 for targets of different sized details and conformations.

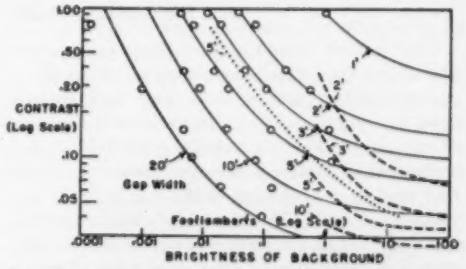


Figure 1. Solid line curves were plotted by Dr. Glenn A. Fry from data by Connor and Ganoung[2] for Landolt Rings. Dotted line is for 5-minute circle on bright surround from data by Blackwell.[3] Dashed lines are for parallel bars from interpolated data by Moss and Cobb.[4]

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The data for the solid line curves of Fig. 1 were taken by Connor and Ganoung[2] for the Landolt broken-circle test object. These curves should be compared with the dotted line curve from data by Blackwell[3] for a solid 5-minute dark circle, and with the dashed line curves from data by Cobb and Moss[4] for the twin parallel bar test object. These curves even for the same size, 5-minute, detail test-object, do not agree very well in the useful range of brightnesses. Configuration, color, surface character, and other factors cause displacement and change of shape of the curves. It seems obvious that a particular test object has its own threshold curve and that this contrast-brightness threshold might well serve as a useful index of the visibility of the test object.

Methods of Measurement of Thresholds

Various means of making threshold measurements are discussed in a comprehensive article by C. Dunbar, published in 1939.[5] His analysis does not lead to any recommendations for acceptable meters but one draws an inference that a particular meter might have advantages for measurement of a particular kind of seeing task. This seemed to indicate the desirability of making some comparative measurements of visual targets, at reading distance, with the well known Luckiesh-Moss Visibility Meter[6] and with a form of contrast-brightness threshold meter somewhat modified in design from the one described by Dr. L. A. Jones[7] and used during the first World War for measuring the effectiveness of ship camouflage at sea. Dr. Brian O'Brien[8] has also developed a similar form of meter for determining the ease of aircraft recognition under different atmospheric conditions. Other forms of threshold meters are described by Dunbar, and their reference cited in his article; but their limitations have resulted in no general acceptance.

The L-M Visibility Meter

The Luckiesh-Moss Visibility Meter consists of a pair of gradient density and diffusion filters which are adjusted so that a visual task seen through these filters just becomes discernible. The reading of a scale of so-called "relative visibility" is then made, and by these readings the "visibility" of one task may be compared to that of another, or to a "standard" task. The meter is used binocularly and the settings are made without much difficulty, though a question may arise as to what effect the progressive change in apparent brightness of the task as seen through the filters, may have on the brightness adaptation of the eye. The error due to this effect could perhaps be reduced if all observations are taken at a constant rate. Fundamentally the meter works on the principle of an arbitrarily selected scale and standard of comparison. However, it has the merit of simplicity of use and convenience of manipulation. A great many measurements have been made with this instrument and its use has been extensively studied.

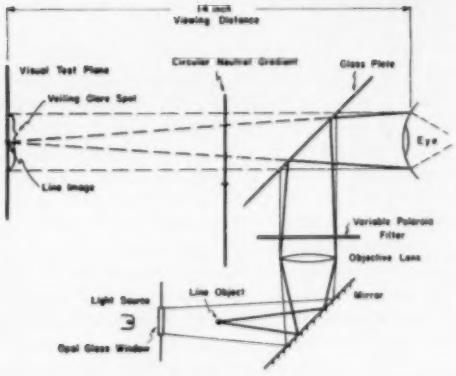
A Contrast-Brightness Threshold Meter

In order to avoid some of the features of the L-M meter which have been questioned, a meter was constructed, in which the contrast-brightness threshold could be determined. Hereinafter this meter will be referred to as the c-b threshold meter. The contrast-brightness threshold was selected as advantageous from the instrumentation point of view as well as from the point of view expressed by Dr. Luckiesh in his book *Science of Seeing* where on page 136 he points out that contrast-sensitivity is more affected by change in illumination than is either speed of seeing or visual acuity. The meter is adapted from a form of projection gun sight (type N6A) in which a luminous field is provided to be superimposed by projection upon a visual target. This veiling-brightness field of about 7 degrees diameter is adjusted in brightness until equal to the brightness of the target background. Then a 5.75-inch circular neutral-gradient filter through which the target is seen, is turned until the target detail is just perceived. The neutral gradient filters were supplied by the Eastman Kodak Co. and are practically free of scattering being made of dyed gelatin mounted between glass discs.

The monocular model is illustrated in the photograph as it is being used, Fig. 2a, and its optical arrangement is shown in the diagramatic sketch, Fig. 2b. Two gunsights were combined to permit binocular use and were arranged so that two neutral gradient filters were adjusted synchronously to always present equal transmission to each eye. The luminous spots of the two gun-sights are made equal by adjusting a polarizing filter on one gunsight, and the voltage of the current supply for both gun-sight lamps is adjusted to produce the desired veiling brightnesses.

The transmission factor (t) of the gradient filters for the threshold setting is observed and recorded. For this condition let B represent the brightness both of the background and of the superimposed veiling spot; let b represent the brightness of the detail, then: $B + tB$ = total brightness of the background, and $B + tb$ = total brightness of the detail, so that the contrast threshold, C, is: $\frac{(B+tB)-(B+tb)}{B+tB}$, or $C = \frac{t\,(B-b)}{(1+t)\,B}$

Figure 2 (a) (Top). A contrast-brightness threshold meter. (b) (Bottom). Diagrammatic sketch of c-b threshold meter.



Now $\frac{B-b}{B}$ is the inherent contrast (C_o) of the target. Therefore, $C = (\frac{t}{1+t})\, C_o$. Let $\frac{t}{1+t}$ be called the "threshold contrast-factor," and this if plotted on logarithmic coordinate paper versus the actual background brightness, (as in Fig. 6), will show the same shaped curves as those for the total contrast-threshold plotted against brightness, but merely vertically displaced by the amount of the logarithm of the inherent contrast of the target. The curves so obtained show the relationships between the various targets observed, and yield a comparison based upon absolute physical properties of the targets and filters, and not in reference to some arbitrary scale or standard. If a value is desired which appears to increase with the ease of discernibility, such a term may be found in the reciprocal of the threshold contrast-factor. However, the logarithmic curves for this quantity versus brightness of background will have the same shape as those for the contrast factor itself, only being inverted. This quantity is called "contrast sensitivity" and may well be a useful index of "visibility."

Experimental Procedure

The experimental arrangement consisted of a two-foot white hemispherical-shell surround in the center of which was located a two-inch window where various targets were presented in different orientations and at reading distance from the observer. The brightness of the surround was uniform and was varied over a range from 1 to 175 footlamberts. Various targets as described in Table I were used.

All targets, except the two of typed letters were presented at various orientations which the observer was required to identify as evidence of his perception. In the letter targets the observer was required to read three words of the Bodoni type, and to identify all letters in the typed letter groups, which consisted only of *o* and *c*. A particular setting was made by approaching the threshold from complete invisibility, and the dials were read by the operator as soon as the perception by the observer was correctly reported. Thus the thresholds so determined were for 100 per cent recognition and were perhaps less definite than the

TABLE I.—Target Numbers and Descriptions.

Target No.	Target Description	Size of Detail at 14 in.	Inherent Contrast
2A	Twin Parallel Bars	2 Min.	93%
5A	" " "	5 "	95%
6A	" " "	6 "	93%
8A	" " "	8 "	95%
10A	" " "	10 "	96%
5C	" " "	5.3 Min.	65%
6C	" " "	6.4 "	67%
8C	" " "	8.4 "	71%
10C	" " "	10.4 "	69%
5D	" " "	5.6 "	46%
6D	" " "	6.8 "	34%
8D	" " "	8.6 "	43%
10D	" " "	11.0 "	35%
8 pt.	8 Point Bodoni type, L-M standard	2 to 5 Min.	about 98%
1	Landolt broken ring	10 Min.	More
2	" " "	9 "	than
3	" " "	6 "	90%
4	" " "	4.1 "	
5	" " "	2 "	
6	5° Split circle, one half slightly darkened	5°	12%
7	½° Split circle, one half slightly darkened and surrounded by a 5° solid black circle	½°	15%
8	Parallel Stripes in 5° circle	10 Min.	More
9	" " " " "	8 "	than
10	" " " " "	6 "	90%
11	" " " " "	4 "	
12	" " " " "	2 "	
13	Typed lower case o and c, groups of 5, on 60% reflect. paper	3 "	50%

point of 75 per cent probability of recognition but were much more satisfactory to the observer in making his settings. The targets selected were largely suggested by Dr. Glenn A. Fry from his experience with visual-target configuration. Tests were made by each of four observers in two separate sittings for each condition. The observers, all of 20/20 vision with no appreciable astigmatism, consisted of a graduate student, a teaching staff member, a secretary, and a mechanic.

The procedure permitted the adaptation of the eyes to the particular brightness level for 15 minutes before observations were begun. Five observations were made of each target at one sitting. The whole series of observations required about 1½ to 2 hours. The sequence of presentation of the targets was a particular irregularity which was reversed for the second sitting of the same brightness condition, and the second sitting was never made on the same day. In fact only one sitting per day was comfortable for each observer. Also the sequence of orientations of the target was completely random except that the orientations were well distributed so as to reduce the influence of astigmatic preferences.

No measurements were made in this investigation for a surround darker than the detail. For use of the c-b threshold meter in this condition, presumably the veiling brightness should be set to that of the detail of the seeing task. Measurements should of course be made to explore the usefulness of the meter when the contrast of the visual task is "negative."

Results

The dependability of the results generally was such that the "probable error" of the mean of each set of five readings was less than about 7 per cent in terms of the numerical quantity observed. In the L-M meters this was in terms of the arbitrary scale of "relative visibilities." In the measurements with the c-b threshold meter, it was in terms of filter transmission. The agreement between the two sets of observations for each condition should be as good as 7 per cent also, but in some cases a difference of as much as 25 per cent existed between the means of the two sets. This seems to be due to the observer using a different criterion for threshold settings from time to time, even to the extent of seeing some targets better than others on one day and vice versa on another day. Often the threshold settings showed an increase in contrast-sensitivity or of "relative visibility" as a sitting

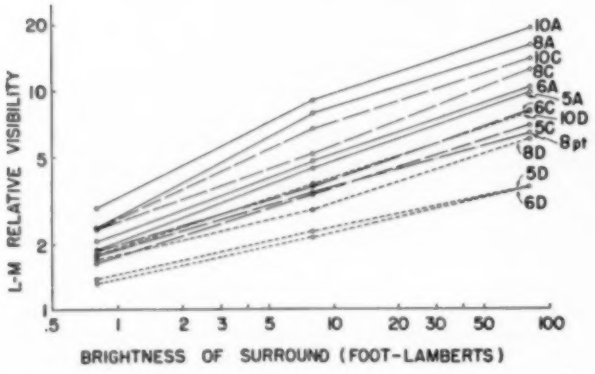


Figure 3. The variation of "Rel. Visibility" with surround brightness as obtained by the L-M visibility meter for the parallel bar test object of various sizes and contrasts, described in the target tabulation.

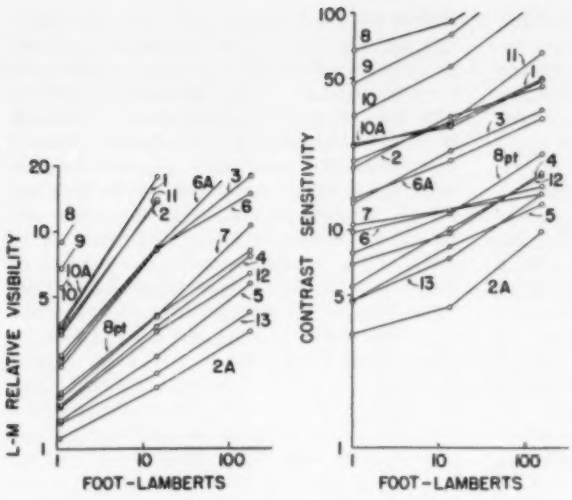


Figure 4 (Left). The variation of "Rel. Visibility" with surround brightness as obtained by the L-M Visibility meter for test objects of various sizes and conformations, described in the target tabulation. Figure 5 (Right). The variation of contrast-sensitivity with surround brightness as obtained by the contrast-brightness threshold meter for the same test objects indicated in Fig. 3.

progressed, and it was to compensate for this that the order of presentation of the targets was reversed in the second sitting for each series with both the L-M meter and the c-b threshold meter.

The observations obtained by the use of each of the meters resulted in the curves shown in Figs. 3, 4, 5, and 6. The separate curves are identified by number corresponding to the particular targets as described in the table. The series of measurements made with the L-M meter on the parallel bar test objects of different contrasts was not repeated with the c-b threshold meter, except for some check observations. These observations showed that at threshold the product of the contrast-factor and the inherent contrast was essentially constant for a given size target. So only the parallel bar test objects of maximum contrast were included in the c-b threshold meter measurements.

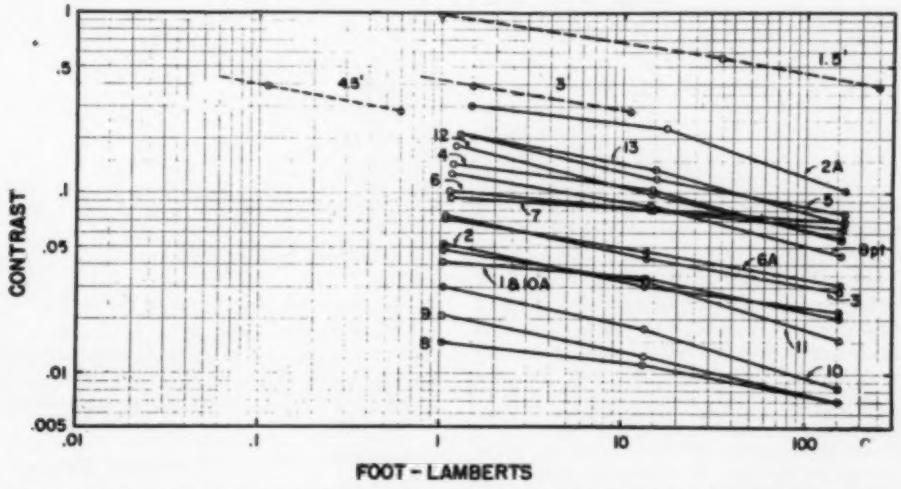


Figure 6. Contrast-brightness threshold curves obtained by the c-b threshold meter for targets as labelled. Compare slopes with the dashed lines plotted from Weston's[11] data for a particular performance rate on the Landolt ring test object; detail sizes as indicated.

Monocular Use of the c-b Meter

By making the instrument monocular its size was reduced to approximately that of a small box camera thus making its use outside the laboratory quite convenient. Monocular meter observations were made, with a diffusing screen in front of the unused eye to maintain constant binocular adaptation. These readings were well within the range of the binocular observations. Confirmation of the agreement of the monocular threshold with the binocular threshold so long as both eyes are adapted to the same surround-brightness was reported by Gassowski[9] in 1941.

A reduction of the background brightness was effected by making the observations while wearing a pair of neutral tinted glasses of known transmission. These observations were found to agree with those made by actual illumination control of the background brightness. Thus a threshold curve for a given seeing task may be obtained by use of the c-b threshold meter without requiring a change in the actual illumination on the task. Neutral tint spectacles are available with transmission of different values. Use might be made of calibrated polarizing filter spectacles as perhaps of greater convenience.

The L-M Meter Considerations and the c-b Threshold Meter

Experimental measurements were also made to investigate the relation of the pure transmission characteristics of the L-M gradient filters to the scattering characteristic, as a function of the R. V. (relative visibility) calibration. This relationship was found not to be a constant ratio but an inverse relationship. Differences in this function were also found to exist between two different L-M meters used in this laboratory. Of course the separate meter calibrations were established experimentally by the manufacturer, using the parallel bar test object, but these calibrations depend upon the particular combination of transmission and scattering properties of the respective neutral gradient filters in each instrument. This raises the question of how the results of different meters may be compared for targets other than the parallel bar test object. In this investigation, however, only one of these L-M meters was used to obtain data for comparison with data obtained by the c-b threshold meter. The data show enough differences to indicate that the R. V. ratings and the contrast-sensitivity ratings are obviously based upon different qualities of the visual targets, and now the question is raised as to which of these ratings may be the more useful.

While the R. V. ratings are conveniently obtained it is not easily possible to use these values to produce the threshold curve for a given task, in a form of log contrast *vs* log brightness. It is conceivable that a particular L-M gradient filter could be calibrated so as to make this possible if diffusion glare is not produced by light sources in the field of view, and if proper precautions are taken to allow for the possible change in eye condition during the observations. But it should be definitely noticed, however, in considering the L-M meter for the purpose of obtaining a threshold curve, that the meter was not designed with this intention. In other words the fundamental purposes of the two meters are somewhat different. A comparison is made here only to emphasize the fact that the c-b threshold meter makes it more easily possible to obtain the contrast-brightness threshold curve. The purely neutral gradient filters have negligible scattering thus avoiding the introduction of veiling-glare by high-lights in the field of view; the eye condition is maintained nearly constant since the field brightness does not change more than a maximum of about 50 per cent increase; and the peripheral field of view practically extends to the limit of vision for both eyes, which is not the case for the L-H meter.

In approaching the setting of threshold-discernibility, sometimes accommodation is relaxed and discernment is not as quickly possible as if the correct accommodation existed. To afford more constant and correct accommodation, the c-b threshold meter may be provided with an adjustment to focus a hair line or other image upon the test target. This can be accomplished with some rulings or marking on the diffusing glass window and focused on the target, and which will then serve as accommodation points even when the target detail is not discernible.

The c-b threshold meter seems to have the following important advantages: (1) presenting results in terms of a single physical property, not dependent upon some arbitrary test object, but merely upon the transmission of a neutral gradient at a particular setting; (2) the maintaining of uniform eye conditions, both in adaptation and accommodations; (3) the relief from results unduly affected by the presence of highlights in the field of view producing veiling glare; and (4) a facility for obtaining enough points on the contrast *vs* brightness threshold curve to determine its character without requiring an actual change in illumination on the task.

Prescribing Illumination

The importance of the contrast-brightness threshold curve as a starting point for prescribing the level of illumination has not been discussed suffi-

ciently, but a beginning has been made in suggestions by Dr. Glenn A. Fry.[10] The writer has compared the constant performance data of Weston's work on the Landolt ring[11] to the c-b threshold curves and has found an essentially parallel relationship, on the log C - log B coordinates, between the threshold curve for a given size broken circle, and the corresponding Weston performance curve. This is shown in Fig. 6 where the Weston data are all for a single rate of performance (not relative performance). Therefore where a simple seeing task of mere discernment is involved, a threshold curve might predict what performance may be expected at a given higher level of illumination.

One must recognize, however, that if more than mere recognition of a simple target is involved, as fo rexample in reading, the same logarithmic increase in brightness from the respective threshold curves will not necessarily yield the same performance rates. Tinker[12] has shown that the speed of reading (performance) *decreases* for type sizes above 12-point type, though separate threshold measurements (not shown here) with the c-b threshold meter indicate continually *increasing* contrast-sensitivity thresholds as the type size increases. This does not mean that a desirable illumination may not still be based upon the threshold values, but the illumination is then set for discernment alone and is not to be based upon the rate of reading which involves a scanning factor as well as other factors in addition to the basic ones of size, contrast, and brightness.

Since with the c-b threshold meter and other similar contrast-threshold meters it is not difficult to obtain threshold curves for various visual targets, it might be desirable to explore further the usefulness of these threshold data as an aid to prescribing desirable levels of illumination. The curves may be obtained *on the job* with the c-b threshold meter here described and comparison may be made between these and the curves of other qualities of the visual tasks. The curves so obtained are independent of any arbitrary scale of calibration and are represented in terms of reproducible physical properties. Of course, they may differ from one observer to another, but the observer may be the particular individual who is specially concerned in performing the visual task and for whom optimum seeing conditions are desired.

Acknowledgments

Acknowledgments are due to the I.E.S. Research Fund for financial support of the work; to the General Electric Laboratory, Nela Park, for supplying a series of twin parallel bar test objects, together with data as to their sizes and contrasts; and to Profs. E. M. Strong and Glenn A. Fry and to Mr. C. L. Crouch for continuing helpful discussion and interest.

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DISCUSSION

GLENN A. FRY*: Dr. Cottrell's paper is an excellent discussion of the design and use of visibility meters in connection with prescribing illumination.

In using the meter, Dr. Cottrell indicates that the veiling brightness field is adjusted until it is equal in brightness to to the target's background. Although several methods of accomplishing the match suggest themselves, it would be helpful to know what method Dr. Cottrell uses and if the relative merits of various methods have been investigated.

A further point which might be considered is the possibility of modifying the instrument to provide for an actual measurement of the brightness of the background of the target. The incorporation of this feature would make it possible for this single device to be used in working out the effect of varying brightness and contrast upon the visibility of any given visual task. As matters stand, a separate device would be required for measuring the brightness of the background. It may prove more economical and efficient, as a matter of fact, to have two separate instruments.

One possibility which ought to be considered is the use of an artificial pupil. In the actual use of the eyes the natural pupils will be used, and hence the visibility of the task ought to be defined in terms of the pupil size which actually exists while performing the task. In using a visibility meter the size of the pupil at the time the threshold is being measured will not be the same as when performing the task. The problem becomes more serious when thresholds have to be measured for different brightness levels. A study ought to be made, therefore, as to whether it is better to make the measurements with or without an artificial pupil.

The same sort of problem comes up in connection with the Luckiesh-Moss Visibility Meter.

No quick answer to the problem appears to be possible, and it seems to be important enough to devote serious consideration to it.

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**Cornell University, Ithaca, N. Y.

pointed for this project by the I.E.S. Research Fund, I have been very close to the research which he here reports on "Measurement of Visibility."

Especially am I conscious of the larger problem which may be reduced by contributions of this nature. I refer to the broad problem assigned to our "Q and Q" Committee, Standards of Quantity and Quality, doubtless the toughest task of our technical committees.

To begin with, the elements "quantity and quality" are not independent variables, and the latter especially is not readily specified or measured. But a major purpose of quantity and quality is to provide visibility, and measures of visibility therefore are desirable both to specify and to appraise the efficacy of an illumination job.

Dr. Cottrell has defined what he means by visibility, first qualitatively and then quantitatively, because the term lacks official quantitative status. The four task factors he identifies as responsible for visibility are widely accepted, yet it commonly occurs that the practical task possesses contrast not only as *brightness* contrast but even more as *color* contrast. It further commonly occurs that the practical task has either no angular size of detail or none that is clearly significant, e.g. a mere boundary between contrasting areas of brightness or color. Sometimes time (of observation) is too ample to limit visibility and therefore is not a measure.

To navigate a useful course among these difficulties it is generally recognized that the color contrast is best ruled out until the less complicated "black and white" is under control; that data in terms of only the two variables, contrast and background brightness, may be relied on generally both to exist and to affect visibility over a usefully adequate range.

Much effort continues to be directed toward a measure and appraisal of visibility in terms of some kind of rate or cost of performance of a visually dependent task. Mr. Allphin's paper on Muscle Potentials* is among these commendable efforts. Until these may attain more certainty of stature, the one possibly acceptable measure of visibility is threshold. It is this still valid philosophy which instigated the L-M Visibility Meter and which justifies interest and effort on the c-b threshold meter.

The quantity and quality of illumination which join to provide threshold visibility for a given task, of course, are not desirable working values any more than the quantity and quality of a boat which may provide a 50-50 chance of getting you from port to port is generally acceptable.

Measurement of threshold does not solve the problem but it can provide a solid first step — a bench mark from which to measure the desired quantity, adequate visibility. Now what is adequate, like the boat, depends on who is going where, in what weather, on what water, for how long. This is a matter of judgment, involving availability of equipment, economic considerations and experience. When the boat is a vessel of commercial proportions and not merely a private sporting craft, the specification of size and quality above "threshold" is not a matter of pure guess, although neither is it an exact science. We aim to do better with illumination than with boats but as yet even the measure of threshold provides room for research and debate.

I believe that Dr. Cottrell's instrument can provide useful data from on-the-job measurements for various tasks—not only *one* threshold point but rather the threshold *curve* for each task over a considerable range of the contrast-brightness variables. More certainty of the pattern of these curves should contribute notably to determining the adequacy of simplified measurement techniques for appraising visibility and for appraising and specifying adequate illumination.

*Scheduled for later publication.

SYLVESTER K. GUTH*: Dr. Cottrell is to be complimented on the development of an interesting method for determining what he has termed the *contrast-brightness threshold*. Instrumentation and techniques of measurement are fundamental necessities in every field of science and engineering. It is possible that this may be a useful alternative method of appraising the supra-threshold visibility of objects and visual tasks.

In essence, the Cottrell c-b threshold meter is used in the same manner as the Luckiesh-Moss visibility meter and produces similar results. That is, as the visibility of an object is increased with higher brightness levels, an observer is able to just barely discern the object through progressively denser portions of the variable density filter. The particular scale that is adopted is relatively unimportant. All scales are arbitrary to a certain extent in that they basically are referred to some scientific relationship. This is true of the metric system and of the contrast-factor scale. The arbitrariness of a scale in no way detracts from its usefulness. In general, a scale needs only to indicate relative magnitudes in an orderly and logical manner that is in accord with experience. It may be of interest to mention that the original experimental model of the L-M visibility meter was called a "visual thresholdometer" and that it was calibrated in terms of the transmittance of the photographic filters.** The present scale was adopted because it was believed to be more logical and rational since higher levels of visibility were indicated by larger numerical values.

The comparison between the Cottrell c-b threshold meter and the L-M visibility meter presented in Figs. 4 and 5 is particularly interesting. An analysis of the curves indicates that both instruments rate the various test objects in approximately the same order of increasing visibility at all three brightness levels. The few deviations and reversals are not great and could be attributed to the limited amount of data. Furthermore, both sets of curves illustrate approximate linearity when plotted logarithmically as shown.

I believe that the ordinate of Fig. 6 should be *contrast-factor* rather than merely contrast. This scale represents values of the *apparent* contrast of a test object as viewed through the c-b threshold meter. The curves indicate that as the brightness of a test object is increased, the object can be just barely seen through progressively denser portions of the gradient. The inherent contrast of the test object remains unchanged regardless of the brightness level. Similarly, the ordinate of Fig. 5, which is the reciprocal of contrast-factor, would perhaps be more suitably designated as *sensitivity factor*. The reciprocal of relative visibility (from Fig. 3) may be plotted and would result in relationships that are similar to those of Fig. 6.

The curves of Fig. 6 are not true threshold relationships as are those of Fig. 1. The absolute threshold for any specific object or visual task usually is represented by the footcandle level (or brightness level) which permits an observer to just barely discern the details of the object. Any higher level of illumination provides some specific degree of supra-threshold visibility. Thus, each curve of Fig. 6 indicates, in an inverse manner, the degree of supra-threshold visibility provided by the various brightnesses of the tasks. This is indicated directly in Fig. 5.

*Lamp Department, General Electric Company, Cleveland, Ohio.
**A Visual Thresholdometer, Matthew Luckiesh and F. K. Moss, *Journal of the Optical Society of America*, 24, 1934, p. 305.

In a recent paper* we presented a new scale of relative footcandles for the Luckiesh-Moss visibility meter. This paper illustrates the relationship between the footcandle levels for various visibility levels and the footcandle level for the absolute threshold for a wide variety of sizes and contrasts of visual tasks. Such a relationship enables the direct determination of the footcandle level corresponding to any desired supra-threshold visibility level.

The foregoing is not intended to depreeate the Cottrell meter, but to indicate that all visibility meters perform the same general function. That is, a visual task is reduced to the threshold of visibility by some suitable means, and the amount of the reduction is used as an indicator of the degree of supra-threshold visibility.

C. L. COTTRELL**: The questions raised by Dr. Fry are important and should have been answered in the paper.

The adjustment of the veiling brightness field to equal that of the task-background was accomplished in these measurements by first determining B by use of the Luckiesh-Taylor Brightness Meter. Then the voltage applied to the c-b meter lamp was adjusted to produce the same B of the veiling brightness field as determined from a calibration curve of B of the field versus voltage applied to the meter lamp.

The other question raised by Dr. Fry concerning use of an artificial pupil may be considered further, but it should be observed that the natural pupil is not much changed in the process of making an observation with this instrument, since the variation of adaptation brightness is less than 2 to 1; whereas pupil area size varies only a maximum of about 16 to 1 for an adaptation brightness change of a million to one. Of course as observations are made at lower brightness levels to obtain the threshold curve, the pupil area may change appreciably, but this might merely mean that the threshold curve for the natural pupil may be different from that for a constant artificial pupil.

Professor Strong's comments are a valuable addition to the paper in clarifying some of the advantages of an approach of this kind to the problem of prescribing desirable levels of illumination, as well as pointing out some of the inherent limitations.

I greatly appreciate the comments of Mr. Guth, but I believe that the "arbitrariness of a scale" may be of varying degree, and that some "scientific relationships" may serve as more suitable bases than others.

Mr. Guth is correct in suggesting that the ordinates of Fig. 6 should properly be contrast-factor.

Reduction of a visual task to the threshold of visibility and using the amount of this reduction as a measure of the degree of supra-threshold visibility does not seem to the author to have unique significance at present. That is, it is not certain that the amount of reduction of one quality of a seeing task to threshold would yield the same visibility rating to a series of test objects as the reduction of another quality would yield. Mr. Guth may be right in his opinion about this matter but as he says our data are too limited to disprove it.

*A New Scale of Relative Footcandles for the Luckiesh-Moss Visibility Meter, Matthew Luckiesh, S. K. Guth and A. A. Eastman, ILLUMINATING ENGINEERING, Vol. XLV, 1950, p. 211.
**Author.

Display Lighting a Store Front

Mercury-vapor street lights have been used for attracting night shoppers to the seven stores in this retail business building, Chicago. The luminaires, spaced twelve feet apart, distribute about ten footcandles illumination on the store-front and sidewalk. The twelve luminaires are mounted eighteen feet above the pavement, on a parapet extending about four feet out from the building front, and are equipped with 15,000-lumen mercury lamps. Photo courtesy of Berry Electric Company, Chicago.

Photographic Representation of Street Lighting, Part I

Introduction

UNCONTROLLED night photographs of street lighting installations are rarely faithful reproductions. For example, the two photos of Fig. 1 show a residential street illuminated by 2500-lumen lamps in open asymmetric reflectors mounted 23 feet high and spaced approximately 200 feet apart. Which is the true representation?

Without some basis for control, accurate photographic reproduction of street lighting is remote. By manipulating the negative, a "before" installation of a street can be made to appear darker, or lighter, depending upon the desired use of the photograph. Recognizing the necessity of using some control for night photographs of street lighting, the I.E.S. Street and Highway Lighting Committee appointed a subcommittee to investigate and make recommendations for a method of producing photographs "truly depicting lighted streets." This interim report of that subcommittee presents the results of its studies thus far.

Report of a special subcommittee of the I.E.S. Street and Highway Lighting Committee. Presented by R. M. Hoot, Chairman of the subcommittee, and J. L. Tupper at the 1949 I.E.S. National Technical Conference. Approved by the Council of the I.E.S., April 1950. Part II is being prepared by the Committee.

The Problem

In the photography of well-lighted scenes, such as those illuminated by daylight, it has been found that in general the most acceptable photographs are those in which the relative brightness and brightness differences in the reproduction bear very nearly an exact correspondence to those of the original. (The term "brightness" as used here refers to the photometric concept of luminous flux emitted per unit projected area.) Under such circumstances in which the brightness adaptation of the observer is not greatly different between viewing the original and the reproduction, a photograph with good objective tone reproduction can be expected to reproduce in the mind of the observer the subjective impression which he received when looking at the original scene. In the photography of lighted streets, however, the problem is considerably more difficult, since the photograph must convey to the light-adapted observer the same impression which he received in viewing the scene while adapted to a *much lower level* of brightness. Tone reproduction theory indicates that this requirement can be met provided information is available on the brightness adaptation state of the observer during the viewing of the original and the repro-

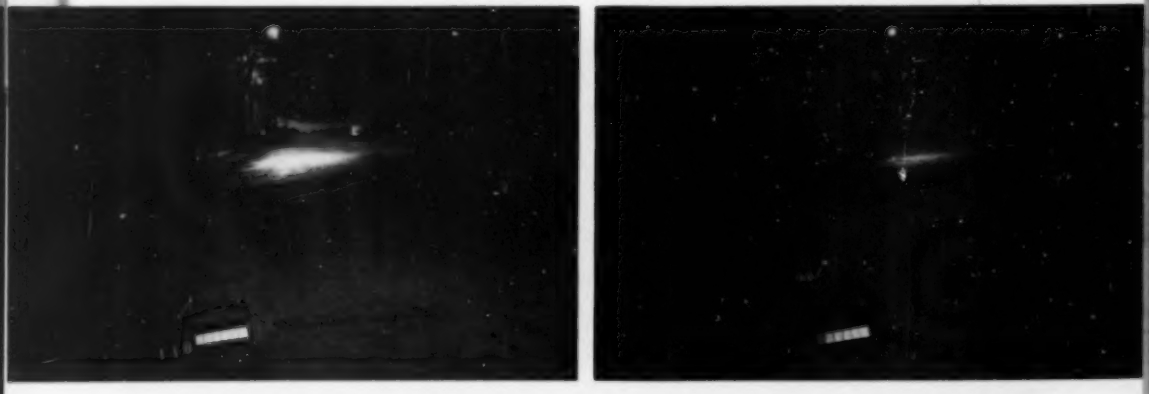


Figure 1. Residential street illuminated by 2500-lumen lamps in open asymmetric reflectors mounted 23 feet high and 200 feet apart. Which is the true representation?

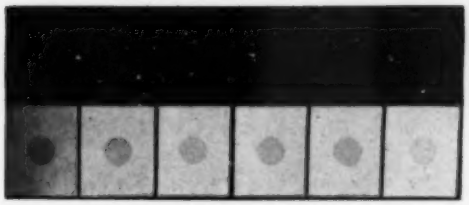


Figure 2. Tupper-Hoot Visometer.

duction. The computation and measurement of the characteristics of the reproduction required to give optimum quality on the basis of such information are very complex, however, and the proposed method has been devised to achieve approximately the same result with a minimum of effort and without special training on the part of the operator or photographer.

Proposed Method

The basic assumption on which the proposed method operates is that if a photograph, viewed under normal lighting conditions, reproduces as a just noticeable difference the same brightness difference which appeared in the scene as a just-noticeable difference to the observer, the photograph will convey the correct impression of the scene. It is assumed, furthermore, that this can be accomplished by reference to a just-noticeable brightness difference at the brightness level of subjective black in the scene.

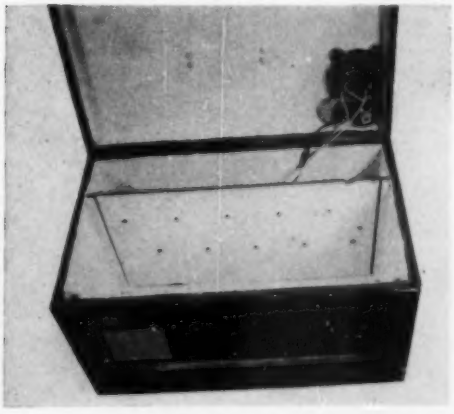


Figure 3. Interior of Visometer showing arrangement of lamps.

The Tupper-Hoot Visometer, which will be described, provides a series of test fields of fixed brightness difference but of different brightness levels. Fig. 2 shows such a Visometer. Fig. 3 shows the arrangement of the 10 2.5-volt (#14) flashlight lamps. Fig. 4 shows the wiring diagram which at present has voltage regulation but for further experiments will be re-wired for finer control by current regulation. Each test field consists of a uniformly illuminated area in the center of which is a slightly darker circular dot. When this box is placed in the scene and these test areas are examined at such a distance that they do not affect

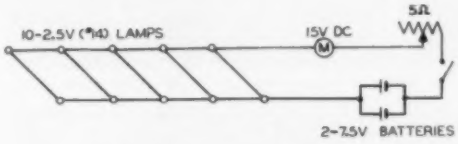


Figure 4. Wiring diagram.

the brightness adaptation of the observer, which is normally controlled by the general scene illumination, the darker test areas will show no dot pattern. At some point between the dark and light limits of the upper row, a test area can be selected in which the dot pattern will be just-noticeable. The brightness of this test area is approximately the brightness of subjective black for this specific condition of brightness adaptation. The actual brightness, B, of the test areas when the clear portion of the lightest test area is held at two footlamberts is shown in Table I.

TABLE I.

Test Area	Test Area Brightness B (footlamberts)	$\frac{\Delta B}{B}$
A1	0.042	0.30
A2	0.029	.30
A3	0.021	.30
A4	0.013	.30
A5	0.0095	.30
A6	0.0064	.30
B1	2.00	0.15
B2	1.26	.15
B3	0.89	.15
B4	0.65	.15
B5	0.47	.15
B6	0.32	.15

The brightness difference between the test area and the darker dot, ΔB, is used to evaluate the fraction, $\frac{\Delta B}{B}$, as shown in the table. The use of the test areas in the lower row will be explained later.

In making the photographic prints of the scene, the correct printing exposure is that which causes the test areas of the upper row to be reproduced on the shoulder of the characteristic *D*-log *E* curve of the paper in a region where the gradient is less than the average gradient of the curve but greater than zero. This can be determined by trial. Provided the negative is fully exposed, it will be found that by increasing the printing exposure, the dot patterns in the test areas disappear successively, starting with the darkest areas first. The desired print is believed to be the one in which the darkest area in which the dot pattern appears is the same as that selected by the observer in the scene. Further field trials are required to test the validity of this assumption.

Although it will be found that with relatively little difficulty prints can be produced in which the dot pattern disappears in the selected area of the upper row, there are other precautions which must be taken in order to insure that the photograph is a reasonably faithful reproduction of the entire scene. The first of these concerns the elimination or reduction of flare light from the street lighting luminaires in the camera. Figure 5 shows the effect of flare. Actually in the original prints it was difficult to see the show windows of the stores due to the flare from the luminaires. Only by clever manipulation in printing was it possible to get this result. Large amounts of flare light will lower the contrast of the camera image in the darker ranges to such an extent that the dot pattern of the upper row may completely disappear in the negative. Adequate shielding of the camera lens and the front panel of the Visometer is absolutely essential. Care must be exercised in the location of the box in the scene, and it is also essential to the successful operation of this procedure that the field areas of the box be critically in focus. Any lack of clarity in the appearance of the dots in the photograph of the test panel will lead to a false impression of the test area at which they disappear.

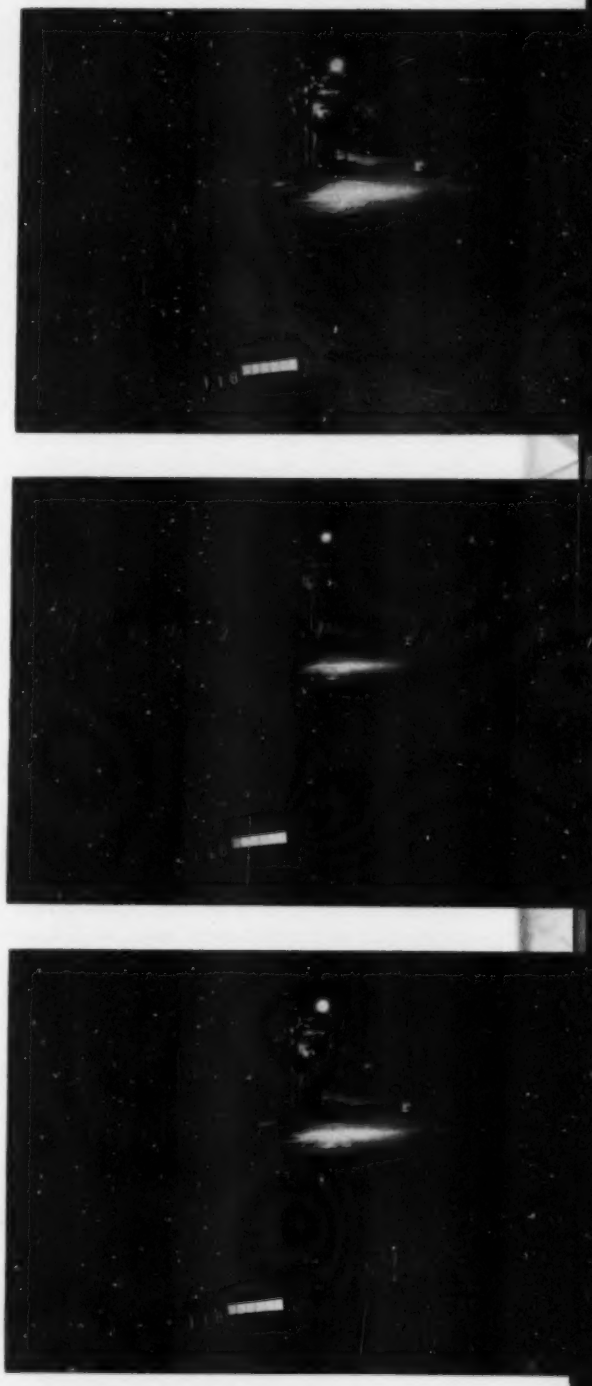
The Visometer is placed in the scene to be photographed at the near side of the depth of focus but in any case not more than 30 feet from the camera. Greater distances make the test areas difficult to see when making the print. It is placed in the street approximately 20 feet past the nearest pole on which there is a luminaire. The camera is then approximately ten feet from the pole in the opposite direction. The lamps inside are regulated to produce two footlamberts on the clear portion of lower right-hand test area. The lower row is then covered and the upper row examined at a distance of about 10 feet to ascertain in which area the dot is just discernible. The number of the test area is noted for future control of the print. The lower row is uncovered and both rows visored so that no light from nearby luminaires falls upon the test areas. A special filter,* which alters the spectral response of panchromatic film to approximately that of the human eye, is placed over the coated lens.

The second precaution concerns camera exposure. It is essential that the darkest area of the upper row be recorded at a point on the characteristic curve of the negative material where the gradient is somewhat greater than one-third of the average gradient. This requires an exposure of about five minutes at f/4.5, or the equivalent, for a film having a tungsten exposure index of 80. It was found that apertures larger than f/9, such as f/4.5 and f/5.6, did not have sufficient depth of field. At f/9 the exposure time is 20 minutes, for f/11—32 minutes, and for f/16—64 minutes. It was found that by focusing for 45 feet with a five and one-quarter inch lens with an aperture of f/11, the control box at 27 feet from the camera would be sharp as well as the portions of the scene some 450 feet distant. However, if greater depth of field is required, f/16 when focused at 35 feet will produce a depth from about 17 feet to 2500 feet. Headlights or tailights should not be allowed to

*For example, Kodak #6431 or equivalent.

Figure 5. Illustrating the effect of flare light from luminaires.

Figure 6. Same scene as Fig. 1: (a) (top) printed too light, (b) (center) printed too dark, (c) (bottom) true reproduction.



register on the film. Therefore, unless traffic can be re-routed or stopped, it is necessary for the person making the exposure to be on guard for cars suddenly coming out intersecting streets or around a distant bend. Traffic conditions will dictate which night hour is most suitable to make the exposures. However, from experience the Committee recommends the period between one a.m. and about one hour before dawn. The negative should be developed to a gamma of about 0.80 in order that it may be printed on a medium grade of paper.

The next important point to be considered concerns the choice of the grade of paper. Most glossy photographic papers have a useful maximum density of about 1.60. This provides a brightness scale in the print of 40. Although the brightness scale of most lighted street scenes is considerably more than this, it is quite possible to produce acceptable prints in which a portion of the brightness scale of the scene is reproduced with approximately correct objective tone rendering. Experience gained from tone reproduction studies indicates that a paper should be selected such that detail corresponding to the darkest shadow and the brightest area of the highlight region of the scene *in which there is interest* should be retained in the print. It is usually not necessary to retain detail in the extremes of the subject brightness scale. To avoid extensive measurement, the proposed method provides a guide to the selection of paper grade by assuming that the test areas of the upper row correspond, on the average, to the darkest scene elements of interest, and the test areas in the lower row correspond to the lightest scene elements of interest. To select the correct paper grade, it is proposed that the test areas in the print be inspected for evidence of dot patterns. The proper paper grade will show the dot pattern to disappear on about the same area in both upper and lower rows. If the paper is too hard, no dot pattern will appear in the lower row when the printing exposure has been adjusted to give the desired reproduction in the upper row. Conversely, if the paper is too soft, all the areas in the lower row will show an obvious dot pattern.

Field Tests

To test the validity and feasibility of this procedure, photographs have been made of lighted streets, and a variety of prints were prepared on different grades of paper with various printing ex-

posures. Observers were taken to the scene and immediately thereafter were requested to select the print which best reproduced the appearance of the scene.

Three test exposures were made of three different streets. The negatives were developed in the Kodak Research Laboratories, and a series of approximately 20 prints of each negative was returned. Each of these series of prints varied from what would appear to be high intensity lighting to extremely low intensity lighting. A total of 14 observers all with more than the average interest in lighting were taken to the actual scenes photographed. Each was told to study the scene, choose and remember an object which to him was just barely perceptible. Their selection of field areas of the Visometer was noted. Then the series of prints of the scene just viewed were spread before them in a room where the illumination was about 30 footcandles. After their eyes were adapted to this higher level of illumination they were asked to select from these 20 prints the one which to them most truly depicted the lighted street previously viewed. This procedure was followed for all three test scenes. A sample of the results showed that for scene "A," 65 per cent of the observers chose print #5, 15 per cent—#3, 15 per cent—#6, and 5 per cent—#4. These four prints were selected out of 20 as best representing the actual scene.

As a beginning these results seemed very encouraging and it was felt that the method was sound, but for an acceptable method closer tolerances were necessary.

Two more scenes were photographed and this time only five prints of varying density of each scene were used. Six observers all familiar with the problem were asked to make their selection. For Scene "H," five of them chose print #2 and one chose #4. For Scene "W" they were evenly split between #1 and #2. It was agreed that a print halfway between #1 and #2 would be acceptable to all.

It will be seen from this second test that from a total of twelve observers, eleven were in accord. These preliminary results indicate that on the average the observers selected prints in which the test panel reproductions conformed to the general requirements set down by this proposal.

Do you remember which photograph you chose in Fig. 1 as being the correct rendition of the lighting on the test street? Whichever you selected you would be wrong. One was intentionally reproduced a little lighter and the other a little darker than the actual. Fig. 6a shows what happens when the scene is printed too light, 6b shows it printed too dark, while 6c is the true reproduction.

Any competent photographer should be able to follow this method after a few hours practice without having special laboratory equipment. Further, all conditions being equal, two photographers, each with his own Visometer, making pictures of the same scene on different nights, should be able to obtain identical photographic results. It must be recognized that in the development of this proposed procedure for obtaining photographs truly depicting lighted streets, certain assumptions have been made and certain short-cuts have been taken which have yet to be fully justified. It should be pointed out that somewhat greater fidelity might be achieved by special techniques and artifices such as retouching, dodging, marking, etc. It is possible, furthermore, that a more natural appearance might be obtained in the photograph if some supplementary lighting is used on the scene during the exposure of the negative. However, it is the intention of this paper to provide a procedure which gives the most faithful photographs within the recognized limitations of "straight" record photography, with the use of commercially available photographic materials and by standard photographic techniques.

Respectfully submitted,

SPECIAL SUBCOMMITTEE ON PHOTOGRAPHIC STUDIES OF THE I.E.S. STREET AND HIGHWAY LIGHTING COMMITTEE

R. M. HOOT, *Chairman*
G. A. EDDY
G. E. KORTEN
E. T. HAWKINS
J. L. TUPPER

Technical Report Subscribers

Each year technical committees of the I.E.S. prepare for publication their reports on important findings on various phases of lighting and new recommended lighting practices. Since many members of the Society have use for every one of these reports in booklet form it has been authorized that a "report subscribers" system be set up in the Publications Office so that these members automatically receive a copy of each booklet immediately upon publication.

Requests for this service should be addressed directly to Publications Office, Illuminating Engineering Society, 51 Madison Ave., New York 10, N. Y.

TELECAST

LIGHTING NEWS OF CURRENT INTEREST

I.E.S. Sponsored Lighting Courses Gaining Momentum

Particular success with courses in illumination have this year been reported by virtually every I.E.S. Section and Chapter. An almost country-wide trend has been the adoption of I.E.S. courses by local universities, these schools making the lighting studies part of their curriculum, but with the local I.E.S. group planning the subjects and supplying the lecturers.

Toronto Section

One such University-I.E.S. series is the Lighting Forum now underway at the University of Toronto, sponsored by the Toronto Section of I.E.S. In one group of studies a series of four sessions is being presented on color, color systems, color and light and the better use of light and color. This specialized subject is being covered thoroughly in monthly sessions by prominent Canadian authorities on color and vision.

Another forum on "Your Home in a New Light" was presented in four sessions during January, also at the University of Toronto. This featured four leading speakers on residence lighting.

Western New York

A series of five lectures on Light and Color was completed late in November sponsored jointly by the University of Buffalo and the Western New York Section. These lectures were of particular interest to architects and were designed toward a non-technical practical presentation of the subject. The lecture schedule included What is Light and Color; Producing Light and Color; Specifying Color; Use of Color in Factories, Schools and Offices; Living with Color.

British Columbia

For a fee of only $2.00, the British Columbia Section is educating close to 400 students with the very practical Lighting Fundamentals Course, which started January 9. The eleven sessions scheduled will be completed March 20. Outstanding local speakers are a feature, with films and demonstrations also planned.

Southeast Florida

Beginning with the 1950-1951 academic year, the University of Miami announced the establishment of a new School of Architectural Engineering which offers a full four-year professional curriculum in Architectural planning and designing, as well as a complete four-year course in Commercial, Industrial and Residential Lighting and Wiring Practice. Illumination was included in this new school largely through the effort of A. C. Bergh, Chairman of the Southeast Florida Chapter of I.E.S., Miami.

Western Pennsylvania

Not I.E.S.-sponsored, but of considerable local value are three training courses for lighting industry personnel put on by the Electric League of Western Pennsylvania, Pittsburgh. The first course, in Fundamentals, was in eight two-hour sessions October 30 through December 18. A weekly series of classes on "Selling Yourself, Your Product and Your Company" began January 8 (through February 12); a course on Advanced Lighting Techniques, weekly also, will begin February 19 to March 26. Registration is $5.00; classes are held at Room 204, 600 Grant St., Pittsburgh.

Montreal Section

This Section also presents its lighting courses in cooperation with a university —McGill. Ten lectures, as part of the University's Extension program, were completed in December, on Advanced Lighting Design and Application.

Philadelphia Section

Philadelphia Section cooperated with Spring Garden Institute for its course in Fundamentals of Illumination, September 8 through December 22—sixteen sessions comprising an especially comprehensive study. An advanced course is scheduled for the spring term, with the faculty for the most part leading members of the Philadelphia Section of I.E.S.

Inland Empire Chapter

Practical training in lighting application was the chief emphasis of the five-session course offered last fall by the Inland Empire Chapter in Spokane, Washington. The lighting training school here attracted many architects, electrical contractors and designers. Fee $2.00.

New York Section

Two courses were planned by the New York Section, both presented in cooperation with the New York University, as part of that school's Extension program. The fall term, concluded January 17, was a comprehensive course in 15 sessions with leading authorities on lighting comprising the faculty. The spring term, date not yet announced, will cover Lighting Design Problems.

In addition to the I.E.S. courses in New York, the Illumination Division of A.I.E.E. conducted an Advanced Seminar on Lighting Design, which will continue through May 2. Classes are held in the Conference Room of the Edison Electric Institute, 420 Lexington Ave., 7:00 to 9:00 p.m. Subjects still to be covered in the Seminar include: February 21, Industrial Lighting; March 7, School Lighting; March 21, Interior Lighting; April 4, Light Sources; April 18, Underwriters Codes; May 2, Light Research. Fee, $1.50 per lecture to nonmembers, $1.00 to members of A.I.E.E., I.E.S. or A.I.A.

Architectural Prize Awarded

Prize winning entries for the second Annual I.E.S. Prize Problem for the students of Architecture at the University of Minnesota have been announced.

First prize, of $85.00, was won by Richard Soderlind of Minneapolis for his solution for lighting a small town historical museum. He used an ingenious arrangement of flexible luminescent panels plus spot lamps for variable displays, and reverse and indirect coves for permanent features.

The winners of the five I.E.S. Student Memberships were, in addition to Mr. Soderlind:

Foster Dunwiddie	Daniel Pates
Robert Sperl	Sheldon Anonsen

This competition is sponsored annually by the Twin City Section of the Society.

GEORGIA SECTION'S display, a feature of the Seventh Annual Conference of the Georgia Citizens' Council, held recently in Atlanta, attracted much attention from the many visitors to the Conference. Note "before and after" schoolrooms demonstrated, and prominent display of I.E.S. publications.

Georgia Section Features Display At Important Local Conference

As a result of the interest in I.E.S. activities developed by the Georgia Section's exhibit last year at the National Safety Council, the Section was asked this year to participate in the Seventh Annual Conference of the Georgia Citizens' Council, held in Atlanta November 9 and 10. This was the first time the Society was represented at this local annual conference. The council was formed as a group to marshall human resources locally, and to formulate citizens' groups at a local level to provide recreation facilities, prevent accidents, reduce disease, etc. All 30 participant organizations in the 1950 exhibit were classed into four groups — safety, recreation, health, and youth — the I.E.S. group being requested to set up an exhibit in the safety group, tied in with the National Safety Council.

The Section's exhibit, topped off by the banner of the section, showed two models of classroom scenes. The one on the left depicted a poorly lighted schoolroom, and on the right was a modern suspended fluorescent installation. The "before" installation had dark woodwork, seats, and dark bookcases set in front of the windows. Desks received direct glare from the windows. Dark floor and ceiling completed the scene. "Too Many Like This" was the descriptive lettering above the model.

To show graphically the improvements obtained from planned lighting and planned classroom environment, the modern installation was equipped with large windows, light walls, green chalkboard, seats properly placed, and adequate shielded light and working space. Lettering above this model stated "Too Few Classrooms Like This." Above each model, respectively, was a poster of a student reading by poor lighting facilities, and by a modern installation. Posters describing street lighting, results of the I.E.S. campaign on street lighting, and magazine articles pertaining to the subject, completed the display.

Copies of all of the I.E.S. publications on lighting for specific fields were well displayed on a table in front of the schoolroom model, and attracted much attention from the many visitors to the Conference.

Winter Quarter Courses Underway in Chicago

Four lighting courses of significance to lighting men are now being held in Chicago, sponsored jointly by the Chicago Section of I.E.S. and the Chicago Lighting Institute.

A 12-session course on "Lighting Design Problems" started January 11 and will continue through March 29, under the direction of R. R. Lusk. The subjects presented at this course reflect the current trend in lighting practice, featuring sessions on luminous ceilings, brightness ratios and color, industrial lighting problems, floodlighting, and numerous subjects of current special interest.

A "Lighting Fundamentals Course," with Robert Ligare of the Chicago Lighting Institute staff as instructor, is also being presented January 10 to March 28.

Starting January 16, in ten sessions to March 20, a course in "Wiring Design" is underway, with Frank R. McShane serving as instructor.

"Present-Day Selling" is the subject for still another Chicago course offered in 12 two-hour sessions through March 26. This is Part B of a similar course conducted during October, November and December. Ralph L. Hazlett serves as leader.

All these courses are held at the Chicago Lighting Institute, 37 South Wabash Avenue, Chicago, with laboratory work, where involved, conducted at the Illinois Institute of Technology.

Award Established for Television Engineering

Establishment of the David Sarnoff Gold Medal as an annual award for an outstanding contribution to television engineering was announced by Earl I. Sponable, President of the Society of Motion Picture and Television Engineers.

"The David Sarnoff Gold Medal," said Mr. Sponable, "will be presented at the society's fall meeting each year to that individual selected by a special award committee who has done outstanding work in some technical phase of the broad field of television engineering, whether in research, development, design, manufacture or operation, or in any similar phase of theater television."

The award was proposed on behalf of the Radio Corporation of America and named for General Sarnoff, chairman of the Board of Directors of that company.

N. Y. Section Residence Lighting Forum Sponsors Decorators' Course

A course on "Lighting Residential Interiors" sponsored by the Residence Lighting Forum of the I.E.S. New York Section is currently underway at the New York University. Designed as a Practical "how to" course for decorators, designers and others interested in the residential environment, the course is being presented in eight sessions, February 20 through April 10, under the direction of Caroline Horn, E.T.L., as Course Coordinator.

Lecturers, provided by the I.E.S. Forum to the University's course, are

all prominent I.E.S. members of the New York Section. Specific lighting problems encountered in present-day homes, and principles underlying the harmonizing of lighting and decoration are special features of the series. Fee for the series is $15.00.

Subjects covered by the N.Y.U.-I.E.S. course include:

February 20 — The Language of Lighting by Priscilla Presbrey, Westinghouse Electric Corporation, Bloomfield, N. J.

February 27 — Available Light Sources and Fundamental Lighting Designs, by Fred M. Wolff, Century Lighting, Inc.

March 6 — Table and Floor Lamps and Lighting Fixtures, by Lucy Hanan, Consolidated Edison Company.

March 13 — Lighting Recipes for the Home, by Lillian Eddy, General Electric Company, New York, N. Y.

March 20 — Visit to Modern Fixture Showrooms: Finland House and Lightolier, Inc., conducted by Caroline E. Horn, Electrical Testing Laboratories, Inc.

March 27 — Architectural and Built-In Lighting Design, by Myrtle Fahsbender, Westinghouse Electric Corporation, Bloomfield, N. J.

April 3 — Modern Lighting in Contemporary and Traditional Interiors, by Gladys Miller, Consultant, New York, N. Y.

April 10 — Color and Light, by Winonah Murphy, Sylvania Electric Products, Inc.

Materials Handling Conference Scheduled

According to the American Materials Society, many problems of materials handling in the electrical industry, including lighting and lighting fixtures, radio and television, will be considered at the Materials Handling Conference to be held at the International Amphitheatre, Chicago, April 30 to May 4.

The National Materials Handling Exposition, being held concurrently, will have many exhibits of interest to the lighting industry.

Census Being Made by I.C.I. of Lighting Organizations

An effort is being made under auspices of the International Commission on Illumination to record the essential data covering all the consequential world-wide organizations which are wholly or partially concerned with illumination, or with radiation closely akin to light. It is not intended to list private clubs, provincial groups nor those societies that deal with vision or lighting only rarely. However, to be included will be any society that is permanently organized (or has regular officers and membership) which does devote all or a considerable part of its affairs to illumination, or has some recurrent activity devoted specifically to production or usage of light, or studies of, or dissemination of knowledge relating to any phase or effect of lighting, vision, and closely related subjects.

A questionnaire is available to be filled out and mailed to:

Mr. Arthur Brainerd
Pres., The U. S. National Committee, I.C.I.
The Philadelphia Electric Company
900 Sansom Street
Philadelphia 5, Penna., U.S.A.

The Committee President will arrange to have all reports edited and consolidated, and the results will be distributed and summarized at the International Meeting, in Stockholm, or as soon as feasible. In advance of that meeting, the report will be distributed to the contributors and to members and interested persons for discussion.

LIGHTING CALENDAR

Society Events

March 4-8, 1951 — Southwestern Regional Conference, Driscoll Hotel, Corpus Christi, Texas

March 22-24, 1951 — Pacific Northwest Regional Conference, Davenport Hotel, Spokane, Wash.

April 5, 1951 — Meeting of I.E.S. National Council, Edgewater Beach Hotel, Chicago, Ill.

April 9-10, 1951 — Southern Regional Conference, Atlantis Hotel, Miami Beach, Fla.

May 9-12, 1951 — Canadian Regional Conference, Chateau Frontenac, Quebec City, Que.

May 14, 1951 — Midwest Regional Conference, Des Moines, Iowa

May 24-25, 1951 — Great Lakes Regional Conference, Hotel Gibson, Cincinnati, Ohio

June 14, 1951 — Meeting of I.E.S. National Council, New York, N. Y.

August 27-30, 1951 — Illuminating Engineering Society, National Technical Conference, Hotel Shoreham, Washington, D. C.

Industry Events

February 15-16, 1951 — Adequate Wiring Bureau Annual Conference, Sheraton-Gibson Hotel, Cincinnati, Ohio

February 22, 1951 — Inter-Society Color Council, Annual Meeting, Washington, D. C.

February 28 - March 1-3, 1951 — Optical Society of America, Washington, D. C.

March 5-9, 1951—Spring Meeting and Committee Week of the American Society for Testing Materials, Cincinnati, Ohio

March 12-15, 1951 — National Electrical Manufacturers Association, Edgewater Beach Hotel, Chicago, Ill.

April 2-5, 1951 — The American Society of Mechanical Engineers, Spring Meeting, Atlanta, Ga.

April 2-5, 1951 — 17th Annual Sales Conference, Edison Electric Institute, Edgewater Beach Hotel, Chicago, Ill.

April 2-7, 1951 — Electric Association of Chicago Industrial Electrical Exposition, Hotel Sherman, Chicago, Ill.

April 3-6, 1951 — Greater New York Safety Council 21st Annual Safety Convention & Exposition, Hotels Statler and Governor Clinton, New York, N. Y.

April 4-6, 1951—Midwest Power Conference, Hotel Sherman, Chicago, Ill.

April 8-11, 1951 — The Electrochemical Society Inc. Convention, Washington, D. C.

April 23-25, 1951 — National Academy of Sciences, Washington, D. C.

April 30 - May 2, 1951 — Chamber of Commerce 39th Annual Meeting, Washington, D. C.

April 30 - May 4, 1951 — The Spring 1951 Convention of the Society of Motion Picture and Television Engineers, Hotel Statler, New York, N. Y.

May 7-11, 1951 — National Fire Protection Association, Annual Meeting, Hotel Statler, Detroit, Mich.

May 17-19, 1951 — Public Utilities Advertising Association, Hotel New Yorker, New York, N. Y.

Week of May 20th, 1951 — National Association of Electrical Distributors, Atlantic City, N. J.

May 27-30, 1951 — American Society of Refrigerating Engineers 38th Spring Meeting, Hotel Statler, Detroit, Mich.

June 4-7, 1951 — Edison Electric Institute, 19th Annual Convention, Denver, Colo.

June 11-15, 1951 — The American Society of Mechanical Engineers, Toronto, Ont., Canada

June 19-20, 1951 — Annual Convention of the Canadian Electrical Association, St. Andrews, N. B.

June 25-29, 1951 — Summer General Meeting, American Institute of Electrical Engineers, Royal York Hotel, Toronto, Canada

July 2-4, 1951 — The American Society of Heating & Ventilating Engineers Semi-Annual Meeting, Portland, Oregon

September 11-20, 1951—Building Research Congress, London, England.

September 25-28, 1951 — Fall Meeting, The American Society of Mechanical Engineers, Minneapolis, Minn.

October 8-12, 1951 — 39th National Safety Congress & Exposition of the National Safety Council, Chicago, Ill.

October 15-19, 1951—Fall 1951 Convention of the Society of Motion Picture and Television Engineers, Hollywood-Roosevelt Hotel, Hollywood, Calif.

November 12-15, 1951 — National Electrical Manufacturers Association, Chalfonte-Haddon Hall, Atlantic City, N. J.

November 25-30, 1951 — Annual Meeting, The American Society of Mechanical Engineers, Atlantic City, N. J.

Chicago Has Lighting Course For Photography

A free course, "Artificial Light in Amateur Photography," is given annually, sponsored by the Chicago Lighting Institute in cooperation with the Chicago Area Camera Clubs Association and the Associated Amateur Cinema Clubs.

Total attendance at last November's sessions was over 1700 for the five-day course. The program, directed by Carl W. Zersen, Managing Director of the institute and an active member in the

Continued on page 9A

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Continued from page 7A

I.E.S. Chicago Section, consists of two lecture periods by top men of the field and a discussion clinic with a panel of experts, each of the five days.

The schedule for last year's course, from November 6 through November 10, was as follows:

Monday — Home Flash Photography and Outdoor Photography with Flash Lamps, Clifton Hyland, Speaker
Still Photography with Floods and Spot and Silhouette Techniques, Gene Johnson, Speaker
Clinic on Flash Photography, Carl Jensen, Moderator

Tuesday — Selection of Lamps for the Job, Carl Jensen, Speaker; Home Reflector Equipment, Ronald H. Smith, Speaker
Exposure Meters, G. C. Andersen, Speaker; Home Flash Photography, Carl Jensen, Speaker
Clinic on Movie Photography, Rush Munder, Moderator

Wednesday — News Flash Photography, A. C. Berardi, Speaker; Exposure Meters, Carl Miller, Speaker
Use of Filters and Color Temperature Effect on Photography, Gene Johnson, Speaker
Clinic on Exposure Meters, Filters, Film, Color Temperature, Gene Johnson, Moderator

Thursday — Black and White Movie Photography and Color Movie Photography, Gene Johnson, Speaker
Speed Light Photography, D. A. Pritchard, Speaker; News Flash Photography, Elliott Robinson, Speaker; Flash Synchronization and Synchronizers, John A. Grant, Speaker
Clinic on Flash Photography and Speed Light Photography, John A. Maurer, Moderator

Friday — Color Flash Photography and Balancing Daylight with Color Flash Photography, Rush Munder, Speaker
Selection of Lamps for the Job, Clifton Hyland, Speaker; Balancing Your Light Source for Color Printing, John A. Maurer, Speaker
Clinic on Flood Photography, Clifton Hyland, Moderator

The sessions are held in the C.I.I.'s offices at 37 South Wabash Avenue, Chicago.

Dr. E. C. Crittenden Retires from N.B.S.

Dr. Eugene Casson Crittenden, Associate Director of the National Bureau of Standards, I.E.S. Gold Medallist, has retired after more than 41 years of service at the Bureau. He is particularly noted for his achievements in the measurement and standardization of light. Another important and far-reaching scientific achievement has been his contribution to the establishment of absolute electrical units based on the fundamental units of length, mass and time, and his work toward having these standards adopted on a world-wide basis. In 1946, he was the recipient of the I.E.S. Gold Medal, highest honor in the lighting field.

For many years, Dr. Crittenden was active in I.E.S. committee work. He was for twenty years chairman of the Committee on Nomenclature and Standards, and was representative from the Society to many other organizations. He was a Fellow of the Society and served as President in 1924-1925.

E. C. Crittenden

For six consecutive years, he was President of the United States National Committee of the International Commission on Illumination, and just before his retirement was made an honorary life member. He was active on the I.C.I. Committees on Vocabulary and on Nomenclature and Standards.

As a tribute to his distinguished government service Dr. Crittenden was awarded, in 1949, the Department of Commerce Gold Medal Award for Exceptional Service.

"Quite a Bag of Tricks"

A sidelight of how the architect feels about illuminating engineering is revealed in a review by John Rannels of *Progressive Architecture* of the series of articles which appeared last fall in ILLUMINATING ENGINEERING. These articles, now published as a 58-page booklet, "Contemporary Lighting in Modern and Traditional Interiors," receive, on the whole, the commendation of architects. "It is quite a bag of tricks that they spread out before us ..." says Mr. Rannels, stressing the need for collaboration between the professions. "Light and vision are the specialty of the illuminating engineers; control of space (setting the stage for all our activities) is the architects' business."

New Luminous Flux Values For Mercury Vapor Lamps

The National Bureau of Standards announces new luminous flux values for mercury-vapor lamps, derived from the new photometric units which were formally established in this country by law in July 1950. Based on the work of L. E. Barbrow and associates of the Bureau's staff, the revaluation places mercury lamps on a basis consistent with incandescent and fluorescent lamps.

Standards of candlepower or luminous flux for the incandescent and fluorescent lamps issued or calibrated by NBS have been based on the new units since 1948 when such values were first introduced in the United States following an international agreement. Changes in values for incandescent lamps thus brought about were relatively unimportant — less than one percent for lamps in common use. No changes were necessary for fluorescent lamps since their development has been so recent that they have always been calibrated in terms of the new units. Changes in the rated values for mercury lamps, however, are as large as 9 per cent for one type.

The mercury lamp standards involved in this revaluation are the 400-watt and 250-watt sizes. The new values assigned are 4.5 per cent lower for the 250-watt and 9 per cent lower for the 400-watt lamps than the standards previously used.

Long-Term Program Announced For Engineering Graduates

Better engineers, fitted for the increasing tempo of technical progress and developed through more efficient use of the first five years following graduation, is the objective of a long-term program announced by the Engineers' Council for Professional Development at its 18th Annual Meeting held at the Tudor Arms Hotel in Cleveland, Ohio.

The program is incorporated in a 200-page compilation of facts and suggestions useful for executives in industry and others in a position to accelerate the professional maturing of young engineers. The study is the result of more than 15 years of work on the part of the E.C.P.D. Committee on Professional Training. Essentially it is a guide which assumes that a young man with potential, and whom the report characterizes as "the most important person in this country today," is willing to contribute heavily in time and effort toward his own development. The engineers picked the five years following graduation as the most important in a professional man's life, since he is then on his own and if the period "can be filled with a helpful program, the further progress of developing the engineer will be a natural evolution." The committee felt that if within the first five years, the young engineer did not organize his thinking and see through the complexities of mod-

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ern industrial life, he would not be able, eventually, to assume leadership.

The E.C.P.D. program is divided into five parts. The first covers the orientation and training of engineering personnel by employers. The committee studied the training programs of 54 companies and reviewed the published information about programs of about 80 other industrial firms. The study showed that the cost of industrial training was minor, and that results after the first year usually held enough promise to convince management that further development and further training were wise. The committee characterizes industrial training as "the first and best opportunity to start the young engineering graduate on a professional development program." The manual gives training-course schedules to help employers to set up effective industrial training programs for engineering graduates.

The second part outlines plans for cooperation in industrial and engineering schools for the continued education of the graduate engineer. "Industrial management must do more than provide orientation and specialized treatment," the committee report states, "it must be concerned with the education of the whole man and employers in industry and government, in cooperation with the colleges, have the responsibility of providing continued education for the engineering graduate." A way of meeting this responsibility was suggested by a subcommittee which surveyed various study programs and found that out of 50 industrial centers, some 23 offered evening study opportunities for engineers through local colleges. For those communities that have no local engineering school, they recommended that local engineering societies encourage industry and the state universities to establish extension centers; that the engineering societies sponsor refresher courses, round-table discussions, and lecture series in specialized fields.

The study gives the results of the survey into educational facilities now available as well as the performances of various companies now operating successful educational programs themselves.

The third section of the report dealt with the relationship of the neophyte engineer with his community. The committee stated that the engineer has a certain responsibility to his community since the public has "made a great investment in him through the taxes and endowment funds provided for higher education. Too many young engineers, particularly in the last few years, have been concerned with the 'rights and privileges' rather than with the obligations and responsibilities which the pursuit of the profession entails," the report stated.

Fluorescent lighting for traffic signs, making them readable from more than 200 feet, has been used successfully for the first time in Portland, Ore. Voltage control provided by a transformer overcomes a difficulty that previously prevented safety engineers from using cold cathode lighting to brighten traffic signs. The sign consists of two cold cathode tubes, translucent white plastic front, ballast and aluminum housing. Photo shows sign with front lowered.

For guidance in integrating the engineer with the community, the committee surveyed present practices and found no cohesive program yet developed. To overcome this, the group said that the responsibility rests first with local sections of engineering societies; second with various community organizations; third with the employer; and fourth with the young engineer himself. Business and service groups were also urged to develop organized programs to welcome newcomers. "Integrating the young engineer into his community will remain a problem only so long as it's a neglected problem." Only a little thought given to its solution in each community will lead to an effective program," the committee concluded.

The fourth part of the volume dealt with engineering registration laws. The viewpoint of the E.C.P.D. committee was that legal recognition does not constitute professional maturity, but rather represents a minimum requirement for engineers. Full professional development depends on continued study and practice of engineering with recognition of responsibility to associates, employer and the public. The committee places on the shoulders of the engineering societies the responsibilities for providing inspiration to carry individuals far beyond the minimum standards of education and experience which are set by the state.

The final part of the study concerns methods and sample tests to help the young graduate make a self-appraisal of his qualifications so that he can redirect himself to take advantage of the opportunities offered.

I.E. on Microfilm

The complete Volume XLIV of ILLUMINATING ENGINEERING is now available on microfilm. This handy film, fitting in any jacket pocket, can be obtained from University Microfilms, 313 N. First Street, Ann Arbor, Mich. at moderate cost.

ABOUT PEOPLE

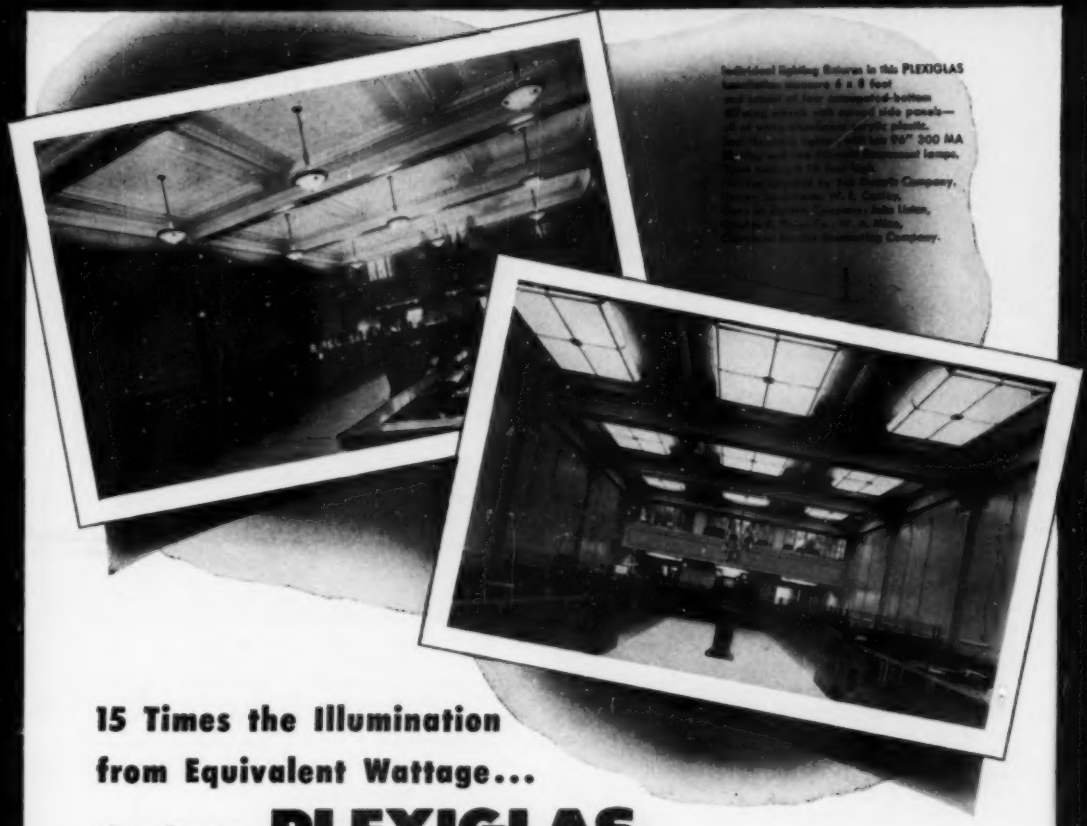
Dr. Irving Langmuir, recently retired associate director of the General Electric Research Laboratory, was awarded the John J. Carty Gold Medal of the National Academy of Sciences, in ceremonies on Oct. 12. These took place during the fall meeting of the Academy, which was held at the G-E Research Laboratory.

The medal, together with an accompanying certificate and honorarium, was given Dr. Langmuir by Dr. Detlev M. Bronk, president of the Academy, who is also president of the Johns Hopkins University. Dr. Herbert Gasser, director of the Rockefeller Institute, who is chairman of the Carty Fund, presented Dr. Langmuir for the award.

The Carty Medal and Award were established in 1930 in honor of the late John J. Carty, a member of the Academy, by his close associates, as a token of esteem on the occasion of his retirement from the Vice Presidency of A.T.&T. The award may not be made more often than once in two years and may be conferred on any one who, in the judgment of the National Academy of Sciences, has made noteworthy contributions to the advancement of fundamental or applied science in any field. In addition to the Gold Medal, and a bronze replica, the bestowal carries with it the award of the net accumulated income since the time of the preceding award.

Dr. Ford E. Williams has been appointed head of the Light Production Division of the General Electric Research Laboratory, and **Dr. Leroy W. Apker** has been made head of the new Semi-Conductors Division. These two

Continued on page 12A



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groups form a part of the recently organized General Physics Divisions. The Light Production Division is concerned largely with studies of phosphors used in fluorescent lamps and television tubes. The Semi-Conductors Division studies materials, such as germanium, which have properties intermediate between conductors and insulators.

E. W. Ritter has been appointed manager of the newly-established Electronic Tube Division of the Westinghouse Electric Corp. Plans are in progress for construction of three new plants to manufacture various types of tubes needed in the defense effort.

Myrtle Fahsbender, director of home lighting for Westinghouse, has been invited to present a paper at the meeting of the International Commission on Illumination in Stockholm next July 4. Her appearance there will make her the first American woman delegate to this world agency.

Robert L. Gibson has been named general manager of the General Electric Company's Chemical Department with headquarters in Pittsfield, Mass. Mr. Gibson was formerly assistant general manager of the department.

The 1950 Hoover Medal was presented to **Dr. Karl T. Compton,** chairman of the Corporation of Massachusetts Institute of Technology by an award board representing the American Institute of Electrical Engineers, the American Society of Civil Engineers, the American Society of Mechanical Engineers, and the American Society of Mining and Metallurgical Engineers.

The award was presented during a general session at the Winter General Meeting of A.I.E.E. on January 22. The award was made to the distinguished M.I.T. scientist as a "Great leader in engineering education, who has had a profound influence on the development of science and engineering, and has devoted himself wholeheartedly to the welfare of the nation, both in times of peace and in times of war."

Chester S. Shaffer, member of the Street and Highway Lighting Committee, has opened an office in Elmhurst, Ill. as consulting electrical engineer specializing in street lighting and other municipal electrical problems. Mr. Shaffer was formerly Superintendent of Electricity for the City of Chicago.

Promotion of **James A. St. Louis** to the position of manager of the Cuyahoga Lamp Works at Nela Park, Cleveland, Ohio, has been announced by Fred F. Harroff, General Electric vice president and general manager of the company's Lamp Department. Mr. St. Louis succeeds **Percy J. Johnson,** who died on November 1 at his Cleveland home. In his new position, Mr. St. Louis will have responsibility for the production of circline fluorescent lamps, sunlamps, mercury lamps, sodium lamps, and quartz repeating flashtubes for photographic needs.

Appointment of four men to the Westinghouse Lamp Division's Research staff has been announced by Edward G. F. Arnott, lamp research director. The appointees are **Dr. John C. R. Kelly, Jr., Martin F. Quaely, Dr. Robert B. Windsor, and Robert Archer.**

At the annual meeting of the RLM Standards Institute, Inc., **S. R. Naysmith,** vice-president of The Miller Co., was elected a new member of the Board of Trustees. The following officers were re-elected: **Rudolf W. Staud,** Benjamin Electric Mfg. Co., President; **E. C. Huerkamp,** Westinghouse Electric Corp., Treasurer; **L. A. Hobbs,** Smoot-Holman Co., Secretary.

James M. Bennan, president of Jefferson Electric Co., Bellwood, Ill., has been elected to the Board of Governors of the National Electrical Assoc. Mr. Bennan has served on various committees identified with the Specialty Transformer Section of NEMA during the past ten years.

Stanley L. Baker has recently been appointed as representative in New England by Day-Brite Lighting, Inc., St. Louis, Mo. A member of the New England Section of I.E.S., Mr. Baker will have headquarters in Ipswich, Mass.

Charles A. Oettinger, a long-time member of the New York Section and formerly lighting sales supervisor for the Newark (N. J.) branch of the Westinghouse Electric Corp., retired from that position October 1st. Mr. Oettinger's connection and services with I.E.S., however, continue from his home in East Orange, N. J.

Peter Mele, President of the Mole-Richardson Co., Hollywood, was elected

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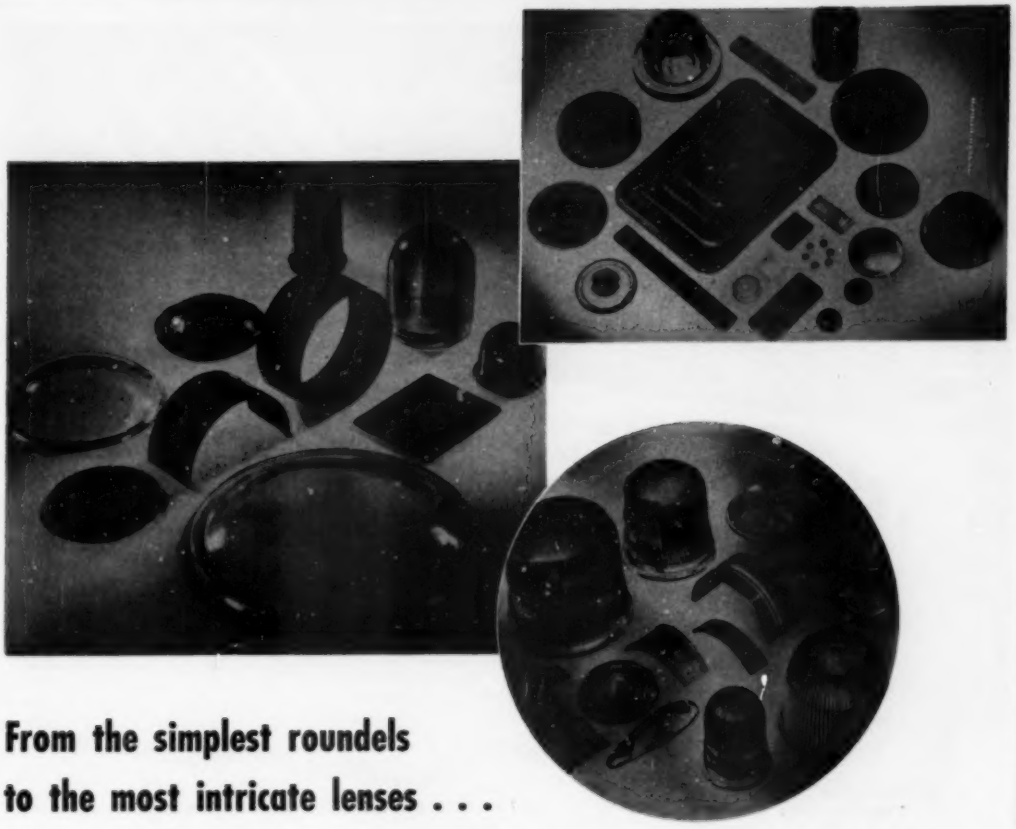
Installations to See When You Visit New York

Building	Address	Lighting
	EAST SIDE	
Tiffany & Co.	727 Fifth Ave. at 57th St.	First Floor—Incandescent, Indirect
Jay Thorpe (Furs)	Fifth Ave. at 57th St.	Fluorescent
Hanan & Sons (Shoes)	16 West 50th St.	Fluorescent
Custom Shirt Shop, Inc.	Lexington Ave. at 50th St.	Louvered Ceiling
John David	Fifth Ave. at 49th St.	Fluorescent
Macey-Fowler	385 Madison Ave. (between 46th & 47th) First floor, N.E. corner	Indirect Fluorescent
Custom Shirt Shop, Inc.	Park Ave. and 46th St.	Downlights
Hutton's Restaurant	Lexington Ave. and 46th St.	Pin-hole Downlights and fluorescent coves
Florsheim Shoes	Fifth Ave. and 43rd St.	Louvered Ceiling
Loft Candy Store	42nd near Madison Ave.	Downlights and Fluorescent
Lane Bryant	Fifth Ave. and 40th St.	Fluorescent including coves
Lobby of 100 Park	100 Park Ave. (between 40th & 41st)	Fluorescent
F. W. Woolworth	Fifth Ave. and 39th St.	Fluorescent
C & A Brennickmeyer	Fifth Ave. and 38th St.	Show window ceiling treatment
Simmons Bed Co.	1 Park Ave. (31st St.)	Fluorescent
	WEST SIDE	
Walgreen's Drug Store	44th St. & Times Square	Slimline
Thom McAn	42nd St., 6th Ave. & B'way	Fluorescent
London Character Shoe Store	Seventh Ave. and 38th St.	Incandescent and Fluorescent
Crawford Stores	Broadway and 34th St.	Fluorescent
Barricini Candy Store	202 West 34th St.	Fluorescent and Downlights, Louvered Ceiling
	DOWNTOWN	
Waterman Pen Co.	Broadway and Fulton St.	Fluorescent
Barton's Candy Store	Cortlandt and Church Sts.	Incandescent and Fluorescent



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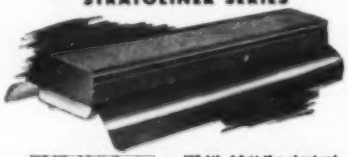
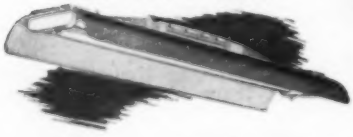
STRATOLINER SERIES



SUO-240—2-light 48-w. open
SUO-340—3-light 48-w. open
SUO-2-100—2-light 100-w. open
SUP-240—2-light 48-w. closed end
SUP-340—3-light 48-w. closed end
SUP-2-100—2-light 100-w. closed end

Durable and strongly built fixtures, neat in appearance. All-steel housing, channel and reflectors. On continuous run wireway installations 2-light sections may be grouped with 3-light or blank sections. One-piece channel for twin 40-watt sections (8' length) or 100-watt sections (10' length).

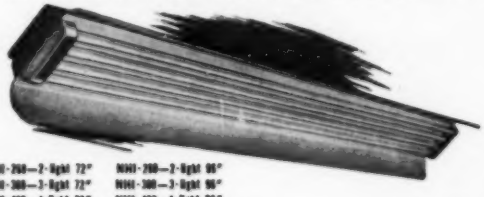
ZEPHYRLITE SERIES



ZUO-248—2-light 48-w. open
ZUO-348—3-light 48-w. open
ZUP-248—2-light 48-w. closed end
ZUP-348—3-light 48-w. closed end

Corrugation incorporates unusual strength and rigidity into units. No warping, twisting or sagging! All-steel housing, reflectors, deep drawn channel. 2-light units can be easily converted to 3-light whenever desired. For individual or continuous run wireway installation.

NEW HORIZON SLIMLINE INDUSTRIAL SERIES



NHU-248—2-light 72"
NHU-348—3-light 72"
NHU-448—4-light 72"
NHI-248—2-light 96"
NHI-348—3-light 96"
NHI-448—4-light 96"

These heavy-duty Slimline fixtures bring streamlined styling to industrial lighting and provide exceptionally high light intensity. All-steel channel and reflectors. Designed primarily for continuous run wireway installations. Instant-start operation in choice of 120, 200, 300 or 425 ma. Multi-bulb units for up to 10 lamps available on special order.

Sold and installed by better electrical dealers and contractors everywhere.

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Continued from page 12A

President of the Society of Motion Picture and Television Engineers at a meeting of the Board of Governors which preceded the opening of the Society's 68th semi-annual convention.

James L. Newton, formerly sales manager of Kopp Glass, Inc., Swissvale, Pa., has been elected Vice-President in charge of sales according to a recent announcement.

Dr. James L. Lawson has been appointed manager of the newly formed Electron Physics Divisions of the General Electric Research Laboratory and Clifford G. Fick has been named assistant manager of this division. Dr. Lawson joined the G-E Research Laboratory as research associate in physics in 1945, and was later appointed head of the nuclear investigations division.

BOOKS AND PAMPHLETS

Electrical Engineers' Handbook, Volume II: Electric Communication and Electronics edited by Harold Pender and Knox McIlwain, published by John Wiley & Sons, Inc., 440 Fourth Avenue, New York 16, N. Y., 1950; Fourth Edition; 1628 5¾ x 8¾ inch pages; price $8.50. This book is a companion volume to *Electric Power* announced in this column last year. The chapter on Optics deals with geometrical optics and electron optics and also contains a 25-page section on vision. Other topics of possible interest to illuminating engineers include Electro-Optical Devices and Medical Uses of Ultraviolet and Infrared Radiations.

Some Investigations on the Illumination of Photographic Darkrooms (and the Determination of the Spectral Sensitivity of Photographic Material) by G. Weber, published by the Academy of Technical Sciences and the Institution of Danish Civil Engineers, Copenhagen, 1950; 278 6¾ x 9¾ inch pages, 166 illustrations.

In the words of the author, who is President of the Danish Illuminating Engineering Society, "The aim of the present work has been to try to attain a somewhat deeper understanding of some of the factors which are of importance to the illumination of the photographic darkroom, so as to make it possible to plan such illumination according to the same principles as those used for the calculation of ordinary lighting systems.

"The problem has for the purpose of the present work been considered from the point of view of the illuminating engineer, while e.g. the photochemical aspects have not been dealt with as they are quite outside the author's sphere of activity. The electrical problems which have presented themselves have, however, been dealt with rather thoroughly. . . ."

After a 40-page introduction the book is divided into four main sections: The Photographic Material, The Physiological Visual Conditions in the Darkroom (including the relative spectral sensitivity of the eye, adaptation, luminence and brightness, contrast sensitivity, glare, and the importance of the physiological conditions), Photometric Units and Measuring Methods, and The Arrangement of Darkroom Lighting in Practice (including light sources, filters, luminaires for general lighting, calculation of the general illumination of darkrooms, lamps for local illumination, wall colors, various forms of "light locks," and a description of the author's experimental darkroom). In an appendix are reproduced spectral sensitivity curves for 15 types of photographic plates. A 17-page bibliography concludes the volume.

A Measuring Diagram for Daylight Illumination by Percy J. Waldram; published by B. T. Batsford Ltd., 122 East 55th Street, New York City, 1950; 19 6 x 10 inch pages, 8 illustrations; price $1.00. This brochure was prepared shortly before the death of the author, to fill the gap caused by letting go out of print the British Illumination Research Technical Paper No. 7, "The Penetration of Daylight and Sunlight into Buildings" which for many years was a convenient inexpensive text giving directions for setting out and using the Waldram diagram. The present booklet gives those descriptions and includes a 12 x 22 inch reproduction of the measuring diagram in common use in England before World War II for interior daylighting problems.

Cold Cathode Fluorescent Lighting, by H. A. Miller, published by Chemical Publishing Co., Inc., Brooklyn, New York, 1949; 138 5½ x 8½ inch pages, 50 illustrations; price $3.75. This is a British book intended for engineers, architects, and "all distributors, users and potential users of fluorescent lighting." The first two chapters give a very simplified Introduction to lighting in general and the phenomena of electric discharge through gases. Succeeding chapters contain much useful information not previously available in one volume. Included are sections on the manufacture and operation of cold cathode fluorescent lamps, auxiliary equipment, examples of a variety of outstanding British lighting installations employing cold cathode tubes, and a summary of over a dozen different forms of luminous tube signs.

A revised edition of the **American Standard Abbreviations for Use on Drawings** has just been published by the American Standards Association. To bring the 1946 edition of the standard up to date with latest industry-wide practice, a committee representing industry, technical associations, government and independent experts developed this new edition. It contains special new sections on abbreviations for colors, valves and screw threads. The section for cable and magnet wire has been greatly enlarged to include colors of cable and magnet wire. Collaboration with the Munitions Board Standardizing Agency of the Department of Defense was maintained at all times and agreement on all common words is expected between this standard and the military standard when MIL-STD-12A is approved. ASA Z-32.13-1950 may be obtained from the American Standards Association, 70 East 45th Street, New York 17, N. Y. at $1.00 per copy.

N.E.M.A. Standards — the following standards have recently been published and are available from the National Electrical Manufacturers Association, 155 East 44th Street, New York 17, N. Y.

Color Markings for Electrode Identification, Pub. No. EW2-1950 ($1.00).

Standards for Flexible Cords — For Multiple-Conductor Flexible Cords with Thermoplastic Insulation and Jacket, Types SVT, SJT and ST, Pub. No. XC1-1950; For Parallel Multiple Conductor Flexible Cords with Vulcanized Insulation and Jacket, Type POSJ, Pub. No. XC2-1950; For Single- and Multiple-Conductor Flexible Cords with Vulcanized Insulation and Jacket, Types S, SJ, SO and SJO, Pub. No. XC3-1950; For Thermoplastic Parallel Multiple-Conductor Flexible Cords, Types POTT 27 Awg. and POT-64 18 Awg; POT-32 18 Awg and POT-32 16 Awg, Pub. No. XC4-1950 ($1.00 each).

IT SEEMS TO ME

To the Editor:

It seems to me that in many respects our Illuminating Engineering Society makes a lot of noise to its own members but really doesn't get anywhere.

Membership: Every year at the Annual Conference and in the Society publication much fanfare is made about increased membership. It is indicated that

Continued on page 26A

cooler operation

only SOLA Ballasts have the patented ventilated capacitor compartment

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A new folder listing electrical and mechanical specifications of SOLA Ballasts is available on request. Write for Bulletin C-PFL-144.

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PUBLICATIONS *of the*
ILLUMINATING ENGINEERING SOCIETY

These publications summarize the studies and conclusions of technical committees of the Illuminating Engineering Society over a period of years. They contain the latest available information about many aspects of the art and science of illumination and include details of application as well as lighting technique. Each publication listed here carries the authority and approval of the Society.

These Society publications are available in single copies for information and for lighting reference book shelves or in quantity for educational or other distribution. Each publication is numbered for ordering when using the coupon printed on the back of this page.

(1) I.E.S. LIGHTING HANDBOOK

One volume, 850 pages. A complete reference guide providing basic information on all phases of lighting. For architects, designers, engineers and others who plan, install and manufacture lighting systems and equipment. $7.50 per copy; $5 in lots of 10 or more.

I.E.S. Members who have not availed themselves of the privilege of one membership copy at $5 may still do so. Add 50c if for shipment abroad.

I.E.S. APPROVED LIGHTING PRACTICES

These booklets contain the latest official I.E.S. lighting recommendations; illustrated with charts, sketches and photographs.

(2) HOME LIGHTING Recommended Practice (1947)

(3) OFFICE LIGHTING Recommended Practice (1947)

(4) STREET AND HIGHWAY LIGHTING American Standard Practice (1947)

(5) LIGHTING PRACTICES FOR STORES AND OTHER MERCHANDISING AREAS (1946)

(6) SCHOOL LIGHTING American Standard Practice (1946)

(7) LIBRARY LIGHTING Recommended Practice (1950)

(8) DAYLIGHTING Recommended Practice (1950)

Booklets above available at 30 cents per copy or in quantity as follows: first 4 copies, 50c each, next 20, 25c each; all over 24 copies, 15c each.

(9) INDUSTRIAL LIGHTING American Recommended Practice (1942)

First 10 copies, 25c each; next 40, 20c each; all over 50 copies, 15c each.

STUDY REPORTS

Lighting recommendations based on recent studies (research, surveys of current practice, and experimental installations) of the I.E.S. Committee on Lighting Study Projects in Industry; completely illustrated. Contain analyses of seeing tasks; recommended quality and quantity of lighting; and suitable lighting methods and systems for both general and supplementary lighting.

(10) LIGHTING FOR WOOLEN AND WORSTED TEXTILE MILLS (1949)

Detailed treatment of lighting for opening and grading, carding, spinning, weaving, and perching. Much of data is also applicable to other types of textile mills.

(11) LIGHTING FOR MACHINING OF SMALL METAL PARTS (1949)

Revision of the 1939 report. Analysis of factors affecting visibility of convex scales, steel rules, scribed marks, center-punch marks, concave specular surfaces, plane and convex surfaces; general shop lighting; and supplementary lighting for various measuring instruments, bench work, machine tools, and inspection of polished surfaces.

(12) LIGHTING FOR FLOUR MILLS (1948)

Close-up photos of visual tasks and levels and quality of illumination for roll, sifter and purifier floors; packing areas; and product control stations.

(13) LIGHTING FOR CANNERIES (1950)

Recommendations based on committee study and research financed by the National Canners Association at Stanford University on general supplementary artificial lighting and daylighting for tasks common to all types of canneries; lighting for color grading and container inspection; and detailed analyses of seeing tasks and suggested lighting layouts for peach, apricot, tomato and olive canning. Data for peaches and apricots may be used as a guide for other light products; tomatoes for medium dark products; and olives for most dark colored foods. Also treated are light sources and equipment suitable for installation in canneries; glare and brightness ratios; sanitation and safety; measurement of light; and adequate electrical wiring.

(14) LIGHTING FOR BAKERIES (1950)

Committee study report on baking industry; complete with photos and drawings of typical floor arrangements and lighting layouts; paint color for visual environment; use of day lighting; lighting levels for various departments; maintenance. Also includes description of use of ultraviolet radiation.

Booklets (10) to (14) available at 50c each; quantity prices upon request.

(over)

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Photographs, drawings and engineering data on actual installations. Sheets punched for binders, available on lighting for metalworking, textile, automobile and other industries; schools; stores; offices; drafting rooms; churches; auditoriums; banks; museums; residences; indoor and outdoor recreational areas; and street and highway lighting.

(15) SERIES XII and XIII—24 sheets each—$1 per series.

(16) SERIES XIV—24 sheets—$1.25 series.

(17) SERIES XV—Subscription for 24 sheets—$1.25.
Delivered throughout year; first group of eight (8) sheets now available; balance in two mailings by January, 1951.

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New style, durable loose-leaf binder bound in blue fabrikoid and attractively stamped in gold. Single binder $1.50; in lots of 25 or more, $1.25.

LIGHTING COURSE MATERIAL

(19) EXPERIMENTS WITH LIGHT
Practical problems suitable for high school science classes. 25c each.

(20) LIGHTING FUNDAMENTALS
Lithograph outline for a one-semester introductory lighting course suitable for college students or adults. $1 each; 10 or more, 75c.

(21) LIGHTING DESIGN PROBLEMS COURSE
Lithograph outline and data sheets for a one-semester course to follow "Lighting Fundamentals." Sections on illumination design methods, brightness ratio calculations, light sources, color in illumination, fixture design evaluation, evaluating lighting installations in the field, bactericidal and infrared energy, and design of installations for office, store, school, industrial and floodlighting. $1.50 each; 10 or more, $1.25.

(22) LESSONS IN PRACTICAL HOME ILLUMINATION
Lithograph outline of a one-semester first course in lighting for utility home lighting advisors, high school and college home economics students, decorators, architects, contractors, builders, and department store lamp department personnel. 25c each.

OTHER PUBLICATIONS

(23) TESTING PROCEDURES FOR ILLUMINATION CHARACTERISTICS (1946)
Five committee reports in one volume: guides to testing fluorescent lamps and luminaires, and street lighting luminaires. $1 per copy.

(24) STANDARD METHOD FOR MEASURING AND REPORTING ILLUMINATION FROM ARTIFICIAL SOURCES IN BUILDING INTERIORS
What to guard against in choosing instruments, where test stations are located and how to take readings. 10c each.

(25) FOOTCANDLE SURVEY (IS-10) FOR ARTIFICIAL ILLUMINATION IN INTERIORS
For use with (24) above, 2c each.

(26) LIGHTING EQUIPMENT ENGINEERING DATA SHEET
For equipment manufacturers and testing agencies for use as a guide in preparing forms for presentation of photometric and other pertinent data on lighting equipment. Also helpful to equipment purchasers as basis for required data. 10c each.

(27) BRIGHTNESS DISTRIBUTION IN ROOMS (1947)
Report #4 of Committee on Standards of Quality and Quantity for Interior Illumination. A set of 28 tables (based on interreflectance calculations) designed for predetermining the brightness of ceiling, walls, floor and furniture for 6 different types of lighting. 50c each.

(28) ART GALLERY LIGHTING (1945)
Completely illustrated guide to lighting exhibits of sculpture and paintings. First 4 copies, 50c each; next 20, 25c each; all over 24 copies, 15c each.

(29) LIGHTING PRINCIPLES AND PRACTICE
A bibliography of selected papers dealing with lighting applications which appeared in the I.E.S. Transactions from 1920 to 1941. 50c each.

(30) GUIDE FOR LIGHTING DATA SHEETS AND LIGHTING PROBLEMS
Instructions for choosing installations and taking measurements, data and illustrations required for submission of I.E.S. Lighting Data Sheets; definition and guide for preparation of I.E.S. Lighting Problems; check sheets for recording data for school, office, store and industrial lighting installations and task view. 50c each.

(31) ILLUMINATING ENGINEERING
The Journal of the Illuminationg Engineer Society. This monthly magazine contains articles on all phases of lighting of interest to lighting engineers, architects, interior decorators and ophthalmologists. Subscription price, $10 per year, plus 50c for delivery abroad; single copies, $1.50 each.

(32) RESIDENCE WIRING DESIGN HANDBOOK
25c each.

(33) FARMSTEAD WIRING DESIGN HANDBOOK
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Booklets (32) and (33) published by Industry Committee on Interior Wiring Design, Room 2630, 420 Lexington Ave., New York, N. Y. Quantity prices upon request.

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Interior Designer: Lloyd Bell, New York City
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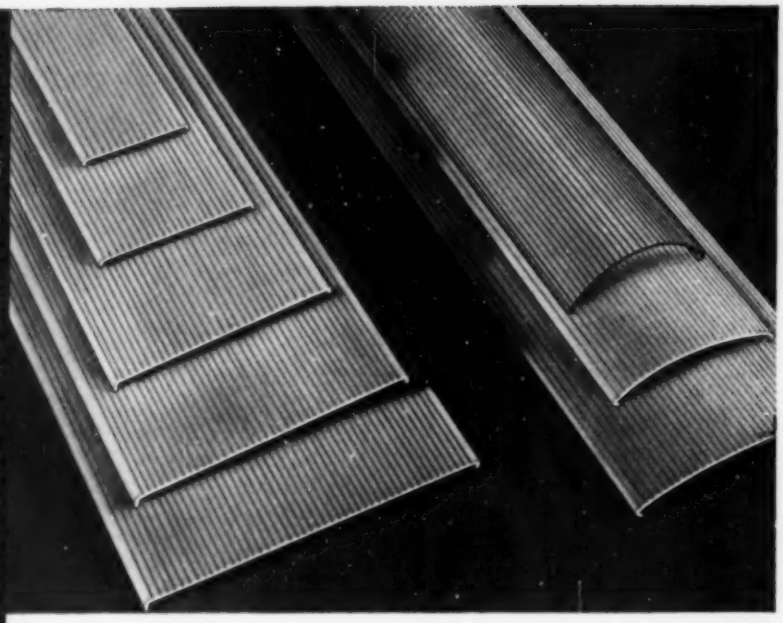

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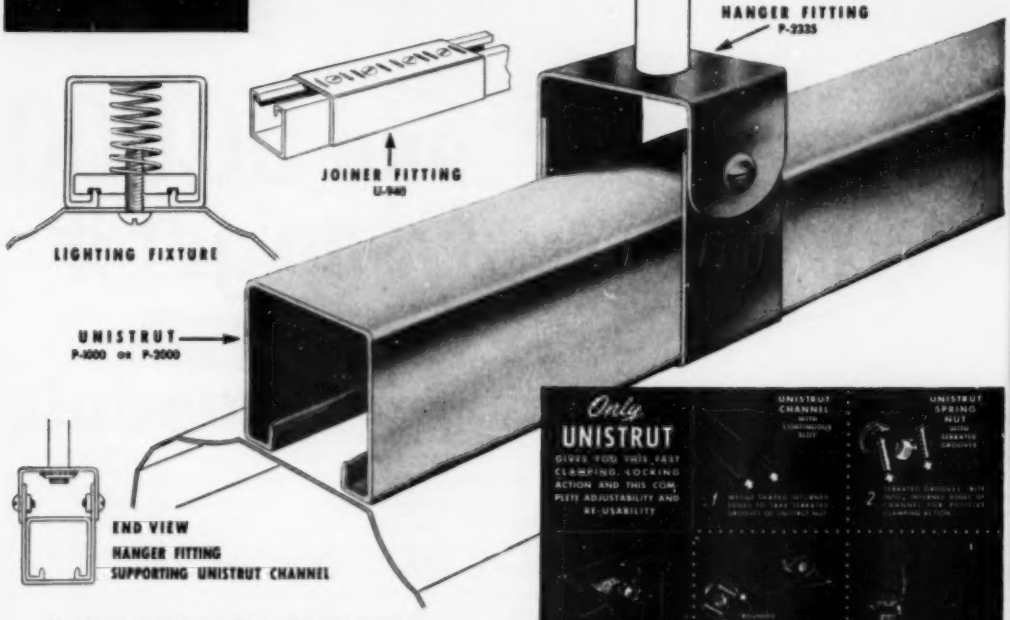

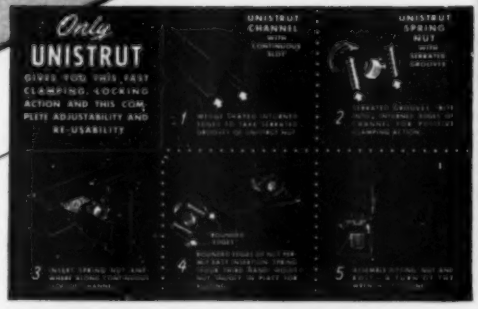
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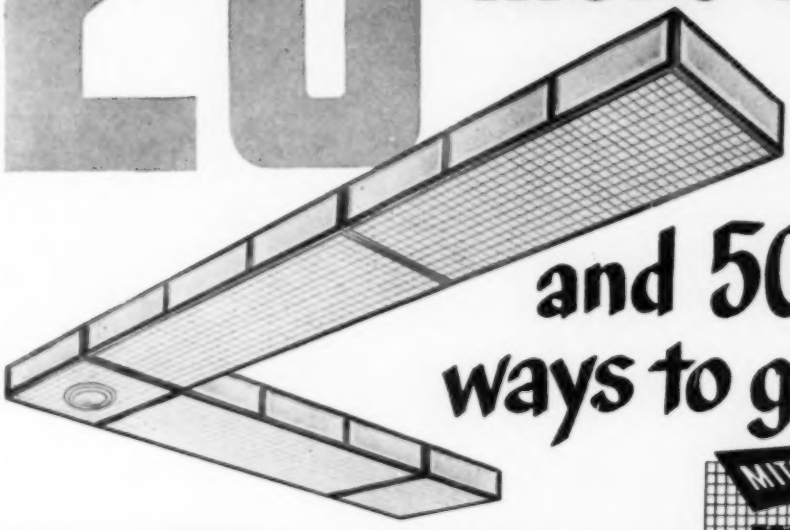

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20% MORE LIGHT! This department store MODULE installation delivers 60 footcandles. To obtain the same light output with ordinary fixtures, 20% more units would be needed.

Yes, MODULE's exclusive Polystyrene plastic louver passes 20% MORE LIGHT than conventional metal louvers—saves more lighting dollars in *any* installation. And with just 4 simple, low-cost "building blocks of light," MODULE creates *unlimited* custom-fitting lighting patterns to fit *any* commercial interior. Because MODULE units fit together simply (both mechanically and electrically), patterns can be rearranged to suit changing needs—*at minimum cost.* MODULE's styling is enduring; stays beautiful, new. No ordinary fixtures can match MODULE—the *only* lighting system that delivers *20% more light*, that *custom-fits* any commercial installation at *lowest cost.*

20% MORE LIGHT! In this modern drug store, MODULE attains a 96 footcandle output. An equivalent number of conventional fixtures would deliver only 80 footcandles.

20% MORE LIGHT! Here is MODULE in an appliance store, delivering 70 footcandles. Using the same number of ordinary fixtures, only 58 footcandles would be obtained.

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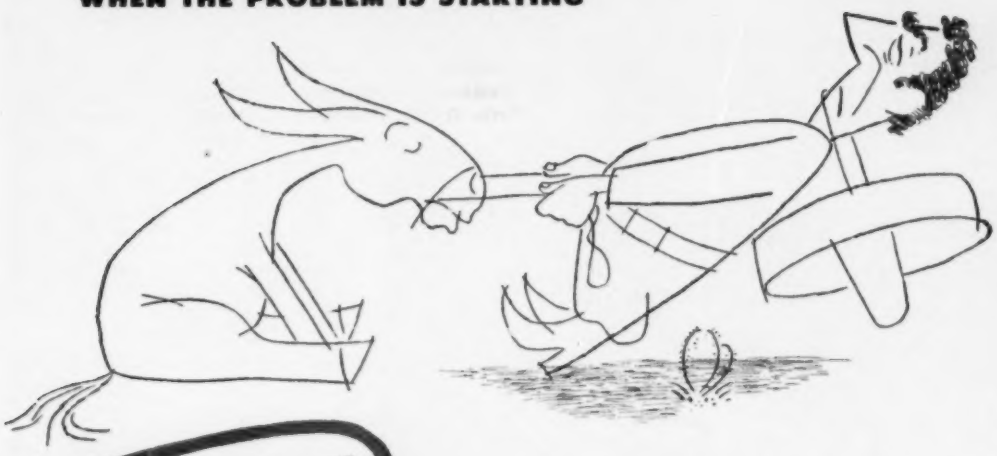

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These starters eliminate blinking and flickering of lamps which have reached the end of their useful life, thereby protecting the ballast and prolonging the life of the starter.

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(Restores the circuit as soon as new lamp is inserted.)

Two pin—for 40, 85, 90 and 100 watt lamps.

Four pin—for 85, 90 and 100 watt lamps.

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(Circuit restored by pushing small red button in top of starter, after new lamp has been installed.)

Two pin—for 15, 20, 30 and 40 watt lamps.

Four pin—for 85, 90 and 100 watt lamps.

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Four pin—for 85, 90 and 100 watt lamps.

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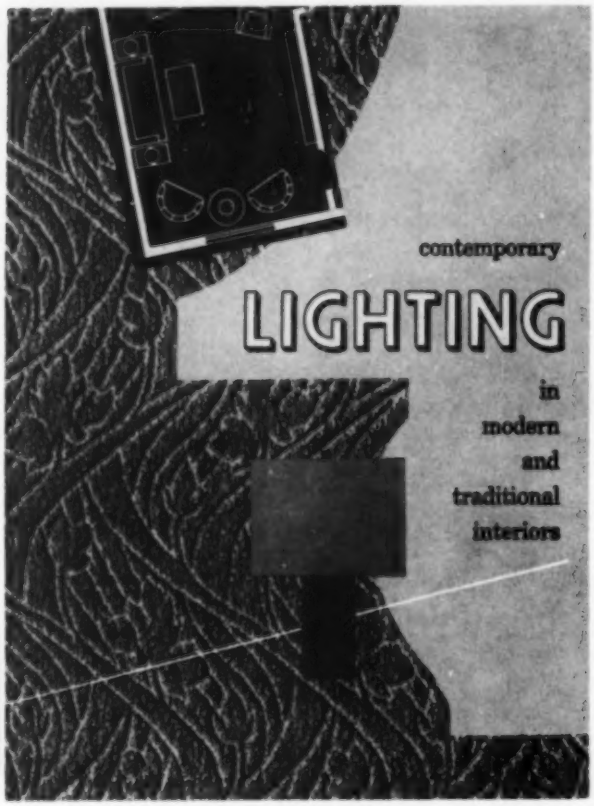
"Contemporary Lighting in Modern and Traditional Interiors"

NEW I.E.S. Committee report combines latest lighting techniques and home decoration into one extremely interesting and practical 64-page volume. With 130 illustrations, the report presents photographs and construction details of numerous new ideas in the use of light and color in different home surroundings from Early American and Colonial through Victorian and modern decorative schemes . . . shows in text and sketches how light can be used for utility and decoration. Lighting data for each typical installation are included.



Both installed luminaires and portable lamps are shown in use in every room in the house except bathroom and kitchen, where lighting techniques are well established. Following are the chapter headings:

Lighting—Its Role in Decoration

Cove Lighting

Recessed Lighting

Window Lighting

Wall Lighting

Ceiling Fixtures and Wall Brackets

Portable Lamps

Lamps for Decorative Accent

Use of Fluorescent Tubes

Guide to Interior Design Characteristics and Motifs

Glossary of Terms—Acknowledgments

This new report has been prepared by a Sub-Committee of the Committee on Residential Lighting. It is particularly useful as a guide to builders, contractors, architectural or interior designers, home-makers, utility company lighting personnel . . . all who are concerned with residential lighting problems.

Use the coupon to order single copies or quantities of this brochure; prices are as follows:

1 through 9—$1.00 each 10 through 99—.90 each 100 through 499—.80 each 500 and over—.75 each

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And good street lighting is appreciated. For example, in Vineland, N. J., when the new lights went on citizens were so pleased, city officials immediately ordered more of the new lighting. The Mayor of Beaver Falls, New York, put it this way, "Our new street lighting is the talk of the town."

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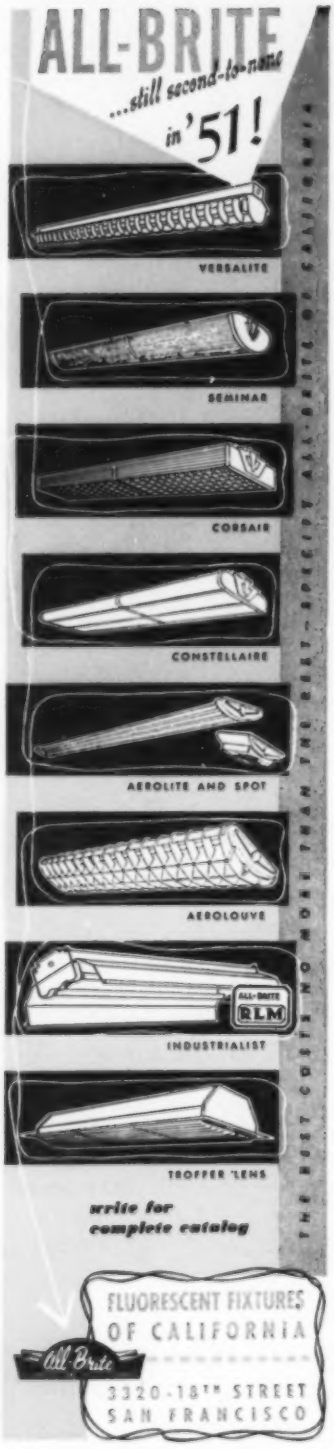

Continued from page 15A

we can measure our growth by the number of new members taken into the Society. By analogy it is assumed that what good we do is synonymous with our membership growth. Nothing could be further from the truth!

I am reminded of the true story of two newspaper publishers arguing over the merits of their respective papers. The one fellow drove home the final point in his argument (?) that his paper was better because his Sunday edition averaged 6½ lbs. in weight while his competitor's paper averaged only 5 lbs. per edition. In any way of thinking we are guilty of the same kind of reasoning when we try to sell the idea of Society growth in terms of membership.

In the annals of history the worth of our Society will *not* be written in the way of improving the lighting and seeing environment of the people who live in our time. If more I.E.S. members would take this attitude I'm sure the esteem of the Society would rise in the minds of the people in our world.

I.E.S. Pins, Where? For a group of people who have joined together to promote the common interests of the lighting profession it seems that the wearing of the Society pin would be almost mandatory. Yet in attending Chapter meetings in various sections of the country I.E.S. membership pins are conspicuous by their absence. I have even noticed that Past Presidents of the Society, when attending trade meetings and Society functions don't bother to wear their Past President's pins. Why? Is the pin in hock? Are they ashamed to wear this badge of honor? If I had a Past President's pin, through rightful ownership, I'd wear it constantly and it could be removed only over my dead body! Must be Past Presidents lose that attitude . . . something I can't quite understand!

The Back Room Boys: Having been a member of the Society for a number of years we are all aware that the management of the Society is in the hands of the "Back Room Boys," who represent a few select members of major lamp companies, utility companies, a sprinkling of educators and manufacturers in business 50 years or more. Year after year we see the same old faces heading up committees — a drop of new blood might scare someone!

The unfortunate part about the whole thing is by the time a man wiggles up the long and narrow road to Presidency (20 years minimum) he has spent so much time with the same group he thinks like the Back Room Boys want him to think. Any original, fresh, uninhibited thinking a President-to-Be might create probably died along the 20-year route. The result of this is our front line I.E.S. management is about as static and frozen in their thoughts and actions as it's possible for any group to be. It's like a husband and wife who after spending 25 to 50 years together begin to look and think the same.

A perfect example of this same, unyielding thinking is the Society Journal, ILLUMINATING ENGINEERING. When the format was changed from the Transactions to the new ILLUMINATING ENGINEERING it was the original intent to change the contents also — getting away from the dreary textbook style toward a new, fresh, breezy, easy reading publication. A half-hearted attempt was made toward this change but as usual the Back Room Boys won out and today the ILLUMINATING ENGINEERING journal is beginning to look exactly like the old, dreary, hard to read Transactions. The only difference is in the size of the magazine —from 6x9" to 8x11".

One important reason for changing the format was because the old transactions was read by only 5% of the membership. I'll lay even money that a readership study at this time would reveal we are slowly but surely falling down and losing readership as the new ILLUMINATING ENGINEERING begins to resemble more and more the old Transactions.

The late George Bernard Shaw said he enjoyed being on the side of the minority because they were generally right. Well there is little doubt that this is a voice expressed by a minority in the Society. Time alone will tell if it is right. —DAN DUNNE, *Lighting Products Inc., Highland Park, Illinois.*

NEW MEMBERS

At the meeting of the Council Executive committee held in New York City on January 11, 1951, the following were elected to membership:

ALAMO CHAPTER

Member:
Whitworth, C. C., Central Power & Light Co., Corpus Christi, Tex.
Associate Member:
Hileman, D. V., Martin Wright Electric Co., San Antonio, Tex.

BALTIMORE CHAPTER

Associate Members:
Riley, J. C., Graybar Electric Co., Inc., Baltimore, Md.
Stinchcomb, F. P., Newton-Stinchcomb Co., Baltimore, Md.

CAROLINAS CHAPTER

Members:
Harney, G. G., Garden City Plating & Mfg. Co., Charlotte, N. C.
Puckett, L. O., Belk Stores, Charlotte, N. C.
Associate Members:
Holmes, A. L., Pittsburgh Corning Corp., Pittsburgh, Pa.

Continued on page 29A

You can't beat this life! Life of Westinghouse fluorescent lamps - 7500 hours*

*You'll get lighting economy at no extra cost!

Yes, the *rated average life* of Westinghouse fluorescent lamps is 7500 hours. That means that in store installations the life is 2½ years; in one-shift factories and offices it's 3 years. No other fluorescent lamp, similarly priced, can top this life.

LAMP DIVISION, WESTINGHOUSE ELECTRIC CORP.
Bloomfield, New Jersey

Gentlemen:

Send me full information on Westinghouse fluorescent lamp savings.

NAME _____ TITLE _____

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STREET _____

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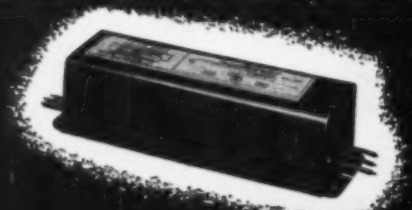
THAT ASSURES
BETTER LIGHT



Acme Electric ballasts have been engineered to eliminate "strobe" effect, provide more lumen output, longer lamp life, quiet operation. Their better performance assure your customer's satisfaction.

ACME ELECTRIC CORPORATION
292 WATER STREET **CUBA, N. Y.**

Acme ACME Electric
TRANSFORMERS

1950 TECHNICAL CONFERENCE
PROCEEDINGS

containing complete preprints of all technical papers presented at the I.E.S. National Technical Conference, Pasadena, Calif., August 21 through 24, 1950.

Since it is probable that all of the Conference papers will not be published in full in ILLUMINATING ENGINEERING, this volume has been prepared for those Society members and others who wish the complete presentation for record or reference purposes.

Available at $2 per copy from:

PUBLICATIONS OFFICE
ILLUMINATING ENGINEERING SOCIETY
51 MADISON AVENUE
NEW YORK 10, N. Y.

Here is a
RARE
Advertising
Opportunity!

SECOND EDITION

IES
LIGHTING
HANDBOOK

Publication October 1951

The Second Edition of the well-known, authoritative I.E.S. LIGHTING HANDBOOK, familiar to thousands of users in all walks of the lighting field, will be available in October, revised in a 900-page volume. With many more pages and almost completely revised, the new HANDBOOK will doubtless receive far greater distribution and use than the First Edition in 1947. As in the First Edition, there will be a complete Manufacturers' Reference Data Section in addition to the 17 sections devoted to technical and practical lighting information. In this section, manufacturers of lighting equipment, components, and other materials essential to a good lighting job present data about products and companies, list local offices, give details and specifications. The section receives wide use in fixture and component specification.

Advertisers in the Manufacturers' Reference Data Section received three times the anticipated circulation from their First Edition insertion, some 20,000 being distributed throughout the lighting field since 1947. Present users of the HANDBOOK include personnel of public utility companies, architects, lighting consultants and decorators, distributors and contractors, professors and students of lighting . . . representing a highly select readership of exceptional advertising value to manufacturers.

While most previous advertisers have renewed and increased their space in the Second Edition, there are some pages available among the limited number allocated to this Manufacturers' Reference Data Section. Reservations should be made by March 15 . . . final closing date for copy is May 1.

Write for rates and copy specifications to: Clayton E. Ellis, Advertising & Promotion Manager.

ILLUMINATING ENGINEERING SOCIETY
51 MADISON AVENUE
NEW YORK 10, N. Y.

Continued on page 26A

Ivey, J. W., J. Frank Blakely Co., Spartanburg, S. C.

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Johnson, G. H., Commonwealth Edison Co., Chicago.

Jurs, W. A., Benjamin Electric Mfg. Co., Des Plaines, Ill.

Jones, C. W., C. W. Jones Electric, Pontiac, Ill.

Kolkebeck, H. J., Commonwealth Edison Co., Chicago.

Lloyd, A. G., Commonwealth Edison Co., Chicago.

Miltenberg, A. M., Garden City Plating & Mfg. Co., Chicago.

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Continued on page 31A

THIS FULLY ILLUSTRATED BULLETIN, IN COLOR, TELLS ABOUT **POWERSTAT**

LIGHT DIMMING EQUIPMENT

SEND for free copy today

THE IDEAL CONTROL FOR SCHOOLS CHURCHES LODGES CLUBS RESTAURANTS HOTELS AUDITORIUMS THEATRES STORES HOMES

The dimming, brightening and blending of illumination is becoming more and more important in the design of new buildings and the remodeling of existing structures. In Bulletin 749 you will find equipment applicable to any job. All POWERSTAT Dimmers carry Underwriters' Laboratories Approval; are available in numerous models and ratings in capacities from 1000 to 30,000 watts.

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THE SUPERIOR ELECTRIC COMPANY

Please send me Bulletin 749 on POWERSTAT Light Dimming Equipment.

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U-D-T Fixture Hangers'
3-way locking speeds installation!

Helpful as another pair of arms, these solid-gripping GUTH U-D-T Hangers allow one man to hang fixtures quickly and securely:

1 Ceiling bridge is attached to ceiling or outlet box.

2 Stems are locked into fixtures and canopy slipped on stems.

3 Stems are hooked onto ceiling bridge and canopy fastened to bridge. Fixtures are leveled quickly with handy set screws atop their channels.

GUTH

NEW LOW-PRICED U-D-T Hangers are available for both single and double stem attachments. See the U-D-T at your GUTH distributor today —or write for Bulletin 873-I.

Guth LIGHTING

THE EDWIN F. GUTH COMPANY / ST. LOUIS 3, MISSOURI

Leaders in Lighting since 1902

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For incandescent and fluorescent lighting equipment, to call on electrical wholesalers, electrical contractors, architects, and engineers. Territories presently open are New York state, Pennsylvania, Maryland and District of Columbia. For further information send complete resume to General Lighting Products Co., 468 Frelinghuysen Ave., Newark 5, N. J.

Continued from page 29A

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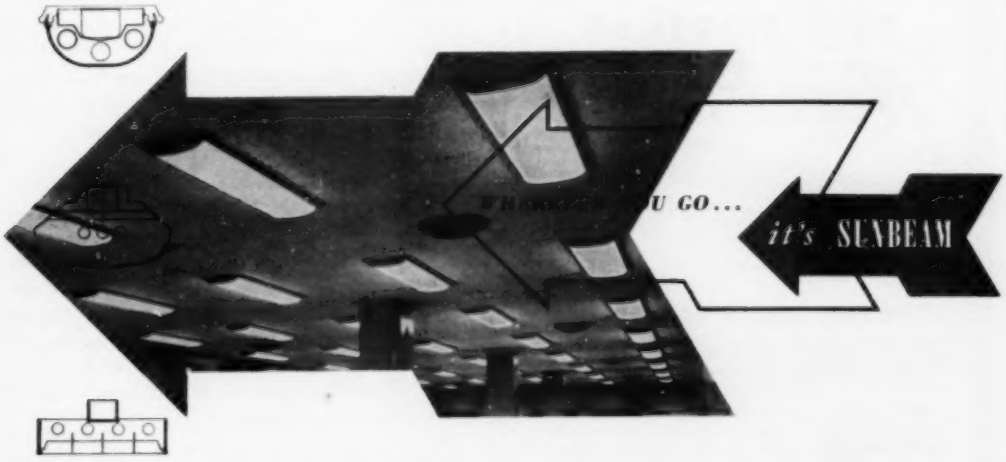

In San Francisco, Houston or Washington, D.C., you'll find lighting installations of high efficiency built around Sunbeam luminaires. The Sunbeam line, one of the most complete in the country, features a fixture design for every lighting problem.

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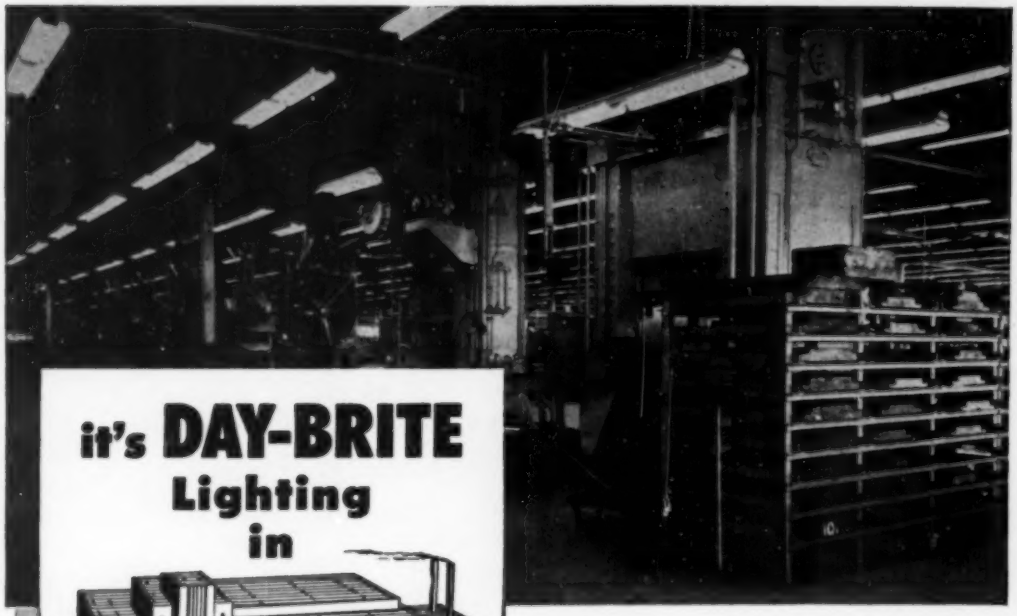
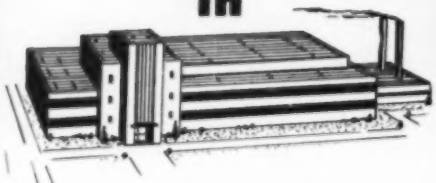


it's DAY-BRITE Lighting in



still another *New Plant*

DAY-BRITE RLM

THE DAY-BRITE "DAY-LINE"

Die-formed heavy-gauge steel. Reflectors finished in porcelain enamel, reflection factor is 82% or more. Reflectors fasten to channel by two extra-large captive wing nuts . . . easy removal without tools. Channel finished in HOT-BONDED aluminum gray enamel. Wired with certified ballasts (ETL approved), vibration-proof TURRET* sockets (on all 40-watt sizes), and NO-BLINK type starters. Basic, Fill-in and Alternate sections may be assembled to form continuous runs of any length.

* *Registered Trade Mark*

Pictured above, you see the punch press line of one of the thousands of new industrial plants that have been springing up all over our still-growing country. The company is proud of the careful planning, the attention to detail that has made this plant a model of industrial efficiency. They're proud, too, of the installation of thousands of top-quality Day-Brite "Day-Line" industrial lighting units—a farsighted investment that is paying handsome dividends.

IS *Your* PLANT LIGHTING PRODUCING OR COSTING?

Is your plant lighting giving you the same competitive advantages that *this* model plant enjoys? Or is it outdated . . . inadequate . . . tough on profits . . . actually costing in terms of excessive spoilage, rejects, and waste? Why let your plant lighting cost you profits when Day-Brite lighting can *help you earn?* Act now! Write Day-Brite today for full information.

Day-Brite Lighting, Inc., 5432 Bulwer Ave., St. Louis 7, Mo. In Canada: Amalgamated Electric Corp., Ltd., Toronto 6, Ont. Distributed nationally by leading electrical wholesalers.

"DECIDEDLY BETTER" DAY-BRITE *Lighting Fixtures*

PREMIUM QUALITY WITHOUT PREMIUM COST

Here are the Answers to the most frequently asked questions about the RLM LABEL

Q What do the initials RLM stand for?

A The "R" stands for Reflector, the "L" for Lighting equipment and the "M" for Manufacturers—*Reflector* and *Lighting Equipment Manufacturers.*

Q What does the RLM Label stand for?

A The label affixed to a lighting unit certifies that the reflector meets the minimum specification and performance standards, determined and established by the RLM Standards Institute.

Q Who sponsors the RLM Standards Institute?

A Incorporated as a non-profit organization, the Institute is sponsored by twenty manufacturers who voluntarily elect to manufacture industrial lighting equipment in accordance with RLM Standard Specifications.

Q How are RLM Standard Specifications established?

A The RLM Technical Committee, with the counsel of outstanding illuminating engineers, continuously reviews present specifications and suggests improvements and prepares new specifications. The Committee's recommendations then are reviewed by the Board of Trustees and finally submitted to the Institute Members for ratification. The adoption of new specifications requires approval by at least 80% of the membership.

Q How does the RLM Label assure conformance to RLM Standards?

A Representatives of the Electrical Testing Laboratories periodically visit the plants of all manufacturers participating in the RLM Specification-Certification Program. These ETL inspectors are authorized to take lighting units right off the assembly line or out of stock at random and make the required tests. They may also obtain test samples direct from distributors' stocks in order to check conformance to RLM minimum standards.

Q Who are the Electrical Testing Laboratories?

A Electrical Testing Laboratories, Inc., 2 East End Ave., New York 21, N. Y., is an independent testing organization which has conspicuously served industry for over 50 years. With this impartial and scientific organization rests the sole responsibility of determining whether or not an industrial lighting unit measures up to every individual quality standard that qualifies it to bear the RLM Label.

Q What are the 4 Basic Tests made by Electrical Testing Laboratories?

A (1) Quality of reflecting surface, (2) Reflection factor, (3) Shielding angle and reflector dimensions, and (4) Photometric test for light distribution and efficiency.

Q In addition to design and construction features that meet certain minimum standards, what else does the RLM Label assure the buyer?

A It provides the buyer with a warranty of uniform quality. In addition to the periodical inspections and tests made by the Electrical Testing Laboratories, the manufacturer warrants that every unit shipped by him meets the published specifications of the Institute.

Q How many different types and sizes of RLM Units are there?

A There are 18 basic types of RLM Units and 35 different sizes made by one or more of the 20 member-manufacturers. At present there is available a total of over 250 different makes and types of units which either bear the RLM Label or are on submittal for testing and certification at Electrical Testing Laboratories.

Q How may I obtain free copies of all existing RLM Specifications and a check list of RLM-Member Manufacturers?

A Send for the 44-page RLM Specifications Booklet and the new RLM Bulletin 1050. Write RLM Standards Institute, Suite 823, 326 W. Madison St., Chicago 6, Ill. Your copies will be mailed gladly without cost or obligation.

RLM STANDARDS INSTITUTE
INCORPORATED
The letters RLM stand for Reflector and Lighting Equipment Manufacturers

65370

QUERY FOR LIGHTING EXPERTS!

Q. How many salesmen on the job here?

Attractive new showroom of Lou Awald Chevrolet, Inc., Kenmore, N.Y., Architect, George D. Goetz. Lighting designer, Raymond P. Conners of Sylvania Electric.

A. 95 Sylvania 3-tube Fluorescent Troffers speed sales in this modern showroom

As a lighting engineer, you of course realize that good salesmanship and good lighting go hand in hand. Most of your customers know this, too.

Now, to help you meet the demands for the best possible lighting, Sylvania offers the latest in improved lighting fixtures and techniques. The above photo, for example, shows an unusually efficient application of overhead troffer lighting.

These special Sylvania fixtures, recessed into the ceiling, leave the entire area flat and unobstructed. They also provide a high level of diffused, glare-free light . . . display merchandise to its greatest advantage.

Available in Different Sizes

Sylvania Ceiling Troffers come in 4- and 8-foot lengths, equipped with 2, 4, or 6, 40-watt fluorescent tubes. Available with glass or louvered shielding, they can be mounted singly or in continuous rows.

Let us tell you more about the possibilities of this modern lighting technique for display rooms, schools, drafting rooms, and offices. For full information address: Sylvania Electric Products Inc., Dept. L-8102, 1740 Broadway, New York 19, New York.

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